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contents 6/2012

SPECIAL SECTION: INTO THE DEEP

Nearly three-quarters of our planet lies under water. Now science is peeling away the mysteries of the ocean bottom.

"We're trying to learn how the lifeblood of the planet works. That means we have to be there."

—OCEANOGRAPHER JOHN DELANEY, PAGE 32

On the Cover: Illustration by Mondolithic Studios

"Language and music are not part of our core—we never evolved to engage in them. The reason we have such a head for language and music is not that we evolved for them, but that they evolved—culturally—for us."

–Mark Changizi, evolutionary neurobiologist at 2AI Labs in Idaho
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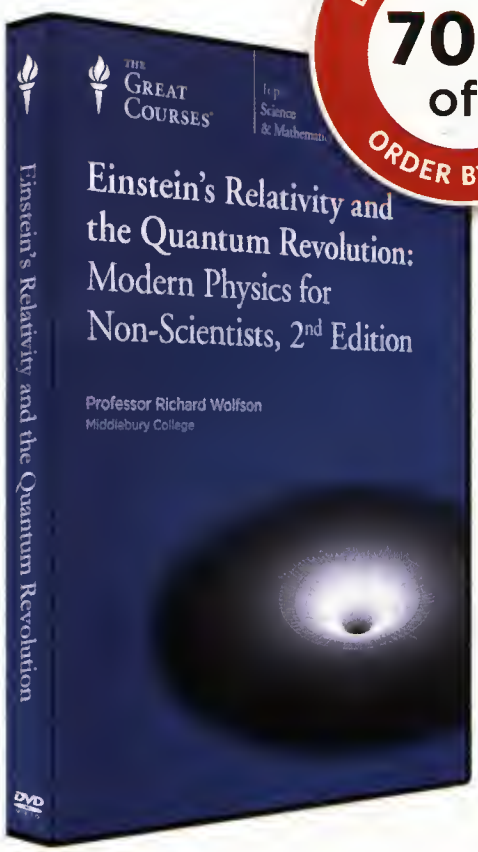

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April 2012

Space Racing

Reviving the Space Age

In "Back to the Final Frontier" (page 52), famed astrophysicist Neil deGrasse Tyson recommended doubling NASA's budget to counter China and other emerging countries that are threatening to overtake American dominance in space.

Tyson hit the nail on the head. The greatest strength of manned launch capabilities is not in the widgets and gizmos, but in the people who design and build them and the vision their work inspires. The engineers who built the Saturn V rocket are in their 80s or deceased. The builders of the space shuttle are in their 60s or retired. Who will replace them? We should retake the lead, develop the technology and the skills, and regain the vision.

Mike Sieverding
Gilbert, AZ

I disagree with Tyson's solution. NASA is a major contributor to the decline of aerospace. If we double NASA's budget, then we have to guarantee that all the new funds go to industry. A cut in NASA personnel would also help the problem: Force their center of attention from building an organization to the specific mission at hand. We got to the moon from scratch in eight years because of the freedom to innovate.

Gary Briley
retired rocket engineer
Paradise, CA

Memory Storage

Researchers have found that specific memories reside in small groups of neurons ("Where Memory Lives," page 30). It all began with an experiment by Richard Thompson, who erased a memory in rabbits by removing a few hundred neurons from their brains.

Thompson's theory that memories can be destroyed by the removal of a few neurons is intriguing, but I'm not sure he should conclude that only the one memory was removed. How does he know that the rabbit didn't lose the memory of the first time it ate a carrot? Thompson is assuming that there were no other memories stored in those particular neurons.

Patricia Maxwell
Kakabeka Falls, Ontario

Author Dan Hurley responds: *Thompson and other memory researchers assume no more than they can prove through experimentation. Thompson is exploring your question, as well as how more complex memories, like what you had for breakfast this morning, are stored. "Some people think those are stored diffusely in neurons throughout the brain," Thompson says, "but I tend to think not."*

Life Above the Clouds?

DISCOVER's cover story ("The Clouds Are Alive," page 38) explored the miles-high microbes that may seed clouds and influence the weather.

The article presumes that the high-flying microbes originate on Earth. That is plausible, but it is odd that these bacteria have amazing abilities, such as surviving extreme desiccation and radiation, that do them no good on Earth. Perhaps they evolved these extraordinary capabilities because they came from a place where extreme cold, desiccation, and intense radiation are the norm: outer space. The brilliant but controversial astronomer Fred Hoyle proposed this idea 30 years ago.

Michael Connelly
Toronto, Ontario

Defining Mental Illness

April's "Number" (Data, page 12) was 82.5, the percentage of children who exhibit mental illness symptoms before age 21, according to a new study.

As an undergraduate I recall being taught that mental illness involved behavior that deviated significantly from the norm in a given society. So it's discouraging to see a statistic like 82.5 percent, which suggests that this so-called mental illness *is* the norm. You quoted psychologist E. Jane Costello, who suggested we "destigmatize the idea of mental disorder." I suggest we take another look at how we define mental disorders.

Russell Mitchell
Dallas, TX

Clarification

In "The Clouds Are Alive," we incorrectly implied that researcher Kimberly Prather believes 80 percent of all cloud seeding might be due to microbes. She was speaking only about clouds she has studied, not all clouds.

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Two Small Steps

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WE LIVE IN AN ERA WHEN THE MERE MENTION OF THE WORDS "government spending" is enough to start a fight. People tend to have strongly held beliefs about something *extremely important* that deserves funding, and equally strong beliefs about where budget cuts should be made—namely, everywhere else. In this current climate, arguing for new money to support basic exploration is sure to raise skeptical eyebrows, or worse. I'm about to do it anyway.

Two articles in this issue greatly help my case. In "Sea Base Alpha" (page 33), writer Ben Hellwarth describes the ragtag group of scientists who are striving to establish modern research colonies on the ocean bottom. The pioneering undersea habitats of the 1960s showed that people could live and explore in unexpectedly extreme environments. "The Wayward Planet Next Door" (page 62) tells the strange tale of Venus, Earth's bizarre near-twin. All the ways that Earth turned out right, Venus turned out wrong: It's searingly hot, bone-dry, and swathed in clouds of toxic acid. We don't really know why, or whether the same things could happen to our world.

Arguing for new money to support basic research is sure to raise skeptical eyebrows.

Lean budgets demand clear priorities? OK, here are two priorities. A major ocean-bottom colony would be far cheaper than the new rockets that NASA is halfheartedly developing. It could be structured as a partnership with universities and private foundations. It would restore some of that old feeling of boundless adventure. A Venus mission, dropping balloon-borne instruments and a temperature-hardened rover, would also be a comparative bargain. The fierce design challenges would help sharpen the skills of NASA's top engineers. Live video from the 900-degree surface of Venus would stir America's next generation of scientists and inventors.

A half-century ago, people asked how we could afford to go to the moon while there were still problems here on Earth. In 1966 NASA's budget peaked at 4.4 percent of total federal spending. This year it is 0.5 percent. For all intents and purposes, NASA has been zeroed out. Did we dispatch all those problems yet—or did we walk away from the kind of glory that inspires solutions?

Corey S. Powell, EDITOR IN CHIEF

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DATA

ICELAND'S GLASS LABYRINTH

The tunnels of an ice cave in southeastern Iceland stretch before photographer Skarphedinn Thrainsson, who stands at the entrance. The cave is just one of dozens within Vatnajökull, Europe's largest glacier: It covers 3,200 square miles with ice roughly a half-mile thick. Vatnajökull's caves change with the seasons. In the summer, part of the glacier's surface melts, forming rivers that snake through the ice to its base. As the glacier freezes over again in the winter, the rivers vanish, leaving behind a network of tunnels. In December Thrainsson hiked up the glacier's snow-covered surface, Ice ax and camera in hand. He quickly found this alcove, with walls as clear as glass, stuck his camera on a tripod, and pointed it toward the opening. Light filtering through the ice turned the cave's walls a luminous blue.

SOPHIA LI

SKARPHÉDINN THRAINSSON

CAT CONFRONTATION

A leopard attacks a forest guard in eastern India. The cat ventured from Mahananda Wildlife Sanctuary last July and was seen lurking in Limbu, a nearby village. Photographer Salil Bera climbed onto a rooftop to watch as guards threw stones at bushes, trying to detect the cat's location. Eventually it came roaring through the shrubs, attacking nearly a dozen people. All survived. The leopard, which had been stabbed and stoned, died en route to a rescue center. Carole Baskin, CEO of Big Cat Rescue, says once a leopard wanders out of a sanctuary, happier outcomes are a challenge. Even with a tranquilizer, it takes at least 20 minutes to sedate a big cat.

SARON YITBAREK

SALIL BERA/ONASIA.COM

Time travel at the speed of a 1935 Speedster?

The 1930s brought unprecedented innovation in machine-age technology and materials. Industrial designers from the auto industry translated the principles of aerodynamics and streamlining into everyday objects like radios and toasters. It was also a decade when an unequaled variety of watch cases and movements came into being. In lieu of hands to tell time, one such complication, called a jumping mechanism, utilized numerals on a disc viewed through a window. With its striking resemblance to the dashboard gauges and radio dials of the decade, the jump hour watch was indeed "in tune" with the times!

The Stauer *1930s Dashtronic* deftly blends the modern functionality of a 21-jewel automatic movement and 3-ATM water resistance with the distinctive, retro look of a jumping display (not an actual jumping complication). The stainless steel 1 1/2" case is complemented with a black alligator-embossed leather band. The band is 9 1/2" long and will fit a 7–8 1/2" wrist.

True to Machine Art esthetics, the sleek brushed stainless steel case is clear on the back, allowing a peek at the inner workings.

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BIG idea

SNAKE OIL CURES FOR DAMAGED HEARTS

Drugs derived from python blood may soon reverse heart failure.

LESLIE LEINWAND GOT PLENTY of skeptical looks from her coworkers in 2006 when she announced her newfound fascination with pythons. Leinwand, a molecular biologist at the University of Colorado at Boulder, was interested in the roots of heart disease, and she noted that the snakes manage to consume vast quantities of fat, yet their hearts stay lean and strong. But snake biology is very different from human biology, and it wasn't clear that any lessons from pythons would translate.

Six years on, her gamble has paid off. Python blood contains a trio of molecules that rapidly bulk up and strengthen heart muscle, suggesting a new approach for combating cardiovascular disease—especially congestive heart failure, a chronic condition affecting 5.7 million Americans in which the heart becomes too weak to pump blood effectively.

Ideally, everyone would have a big, muscular heart like that of an elite athlete, kept strong through constant exercise, Leinwand says. Instead, many people develop enlarged hearts for the wrong reasons: Factors such as obesity and high blood pressure introduce so much stress that the heart stretches out to compensate. It gets bigger but less efficient. That can lead to heart failure, along with an increased risk of fatty buildup and heart attacks.

For years, researchers like Leinwand have looked for ways to promote the good type of heart growth and counteract the bad. Their lab animals of choice were mice and rats, whose physiology is similar to that of humans.

Then, in 2005, Leinwand read a paper in *Nature* that made her rethink that approach. The article encouraged her to look beyond common lab animals in favor of

Burmese pythons, creatures whose metabolic engines run in overdrive. A 20-foot-long python can fast for a year and then consume prey 1.6 times its body weight, equivalent to an average-size man's swallowing a 300-pound steak in one gulp. Within a few days of feasting, a python's metabolism increases 40-fold as the animal rapidly digests the meat and uses up oxygen.

For Leinwand, the most impressive thing about this feat was the ability of the creatures' hearts to keep up—after all, the body can consume oxygen only as quickly as the heart can shuttle it around. To shoulder the load, python hearts grow 40 percent within a day or two of a good supper. The hearts add muscle at a breakneck pace, and their cells fill with beneficial proteins and enzymes.

Leinwand realized that pythons must have something in their blood that injects extra horsepower into the heart when activated by a large meal. A pill that could do the same for humans would go a long way toward treating and perhaps preventing heart failure. (Current drugs like ACE inhibitors improve blood flow but don't actually strengthen the heart.)

At that point, it didn't matter that Leinwand had never seen a Burmese python. She had found her next project. "I'm the sort of person who loves a challenge," she says.

HEART OF A SNAKE

In early 2006 Leinwand ordered 20 baby pythons from a reptile supplier and set up a colony in an empty laboratory downstairs from hers. For the first experiment, she drew blood from a couple of snakes, fed them a big rodent meal, then took another sample. The post-meal blood looked like a cardiologist's worst nightmare. "The blood became so filled with fat that it was almost milky," Leinwand recalls.

In humans, fat in the bloodstream tends to produce fatty deposits on arterial walls and in the heart itself. Yet when Leinwand inspected the snakes' hearts, she could not find any accumulating fat deposits. She realized that whatever chemical was strengthening the heart was also preventing the buildup of fat. She still had no idea how the pythons did it or whether the process would work in other animals, but she was determined to find out.

Part of the issue was settled when Cecilia Riquelme, a postdoc in Leinwand's lab, drew blood from recently fed pythons and applied it to a dish of living rat heart cells. Within two days the cells had grown significantly and were filled with helpful proteins and enzymes. Riquelme's simple experiment suggested that mammals, perhaps including humans, could benefit from the heart-bolstering chemical machinery of pythons.

Leinwand was emboldened to identify that machinery in python blood. It was no easy task: Blood contains thousands of compounds, and any combination of 2 or 20 could have held the secret to heart health. So she isolated compounds in pre-meal blood samples and looked to see if their concentrations shot up after feeding. Whenever she found a candidate, she injected it into mice, hoping their hearts would grow.

After two years and dozens of dead ends, Leinwand finally found a compound that strengthened mouse hearts. She tried it on unfed pythons too, and it triggered the same effect, as if they had consumed a giant meal. The crucial recipe was a mixture of myristic acid, palmitic acid, and palmitoleic acid, all of which were isolated from the milky part of the blood that Leinwand had observed in her first experiment. Ironically, a trio of fatty compounds held the key to strengthening the heart, which in turn prevented other fats from clogging up the works. Leinwand's results appeared in *Science* last October.

PYTHON THERAPY

Now Leinwand wants to observe python blood's effect on at-risk test subjects. Over the next several months she will breed mice with high blood pressure and inject them with the key fatty acids. She hopes the trial will show that a python-inspired pill could treat heart failure by reversing damage and adding heart muscle. Leinwand is also injecting healthy mice to see if python blood can prevent symptoms of heart failure before they start.

Although human drug trials are several years away, Leinwand has cofounded a company to fund her research. Her colleagues hope this work will keep her occupied for a long while. "Everyone has made me promise not to bring another exotic animal into the lab," she says. "They think one is enough."

ANTHONY KING

EXOTIC MEDICINE

Pythons are not the only exotic animals whose body fluids have inspired serious drug research. A variety of outlandish reptiles, arachnids, and mammals also have the potential to overturn their frightening reputations and help fight disease. MARY BETH GRIGGS

GILA MONSTERS These nearly two-foot-long lizards use their poisonous bite to prey on small animals in the southwestern United States. But scientists figured out how to harness the monsters' venom, and in 2005 the Gila-inspired drug Byetta was approved as a treatment for type 2 diabetes.

TARANTULAS Scientists at the University of Buffalo discovered a compound in tarantula saliva that could disable the faulty mechanism that destroys healthy muscle in some people with muscular dystrophy. The researchers are now raising money to start a small-scale clinical trial.

VAMPIRE BATS The saliva of these blood-consuming predators contains an anticoagulant, dubbed draculin by the researchers who found it, that can dissolve blood clots. A new drug based on that chemical, currently in human trials, could give doctors more time to treat people who have just suffered a stroke.

FROM TOP: ISTOCK (2); JOEL SARTORE/GETTY IMAGES; OPPOSITE: MARTIN HARVEY/GETTY IMAGES

TOOLS OF THE TRADE

A Disease Diagnostic for the Developing World

WHEN BIOMEDICAL ENGINEER RICK Haselton visited New Delhi's largest public hospital last year, he saw glaring inefficiencies. One of the biggest: Patients were traveling great distances and staying for days just to get routine blood tests for infection. They had no choice, since many outlying regions lacked well-equipped reference labs and tools to purify samples. But if remote clinics could handle the testing, Haselton thought, then the hospital could focus on the sick while the rest stayed home.

The solution, developed by Haselton and colleagues at Vanderbilt University, was the extractionator, a tool that keeps body fluids sterile while tiny magnets extract disease **biomarkers,** like proteins or bits of DNA, that can be the telltale sign of an infection. To diagnose malaria, for instance, a **blood sample** is fed into a closed **plastic tube** filled with millions of tiny **magnetic beads** coated with nickel. Nickel chemically binds to a protein produced by the malaria parasite, called histidine-rich protein 2. Once the protein attaches to the beads, another larger **magnet** slides along the outside of the tube, dragging the combo through a series of chambers. One chamber washes **contaminants** from the beads; another contains a salt that binds to nickel, causing the biomarker to detach. Then researchers put the purified sample onto a cheap, rapid diagnostic chip. The chip detects the telltale protein, signaling a positive result for malaria.

Haselton plans to identify other pathogens by coating the beads with substances that bind to other biomarkers. Silica, for instance, picks up bits of DNA that can be used to diagnose tuberculosis. The tool could also provide an inexpensive way to test drinking water. JOSIE GARTHWAITE

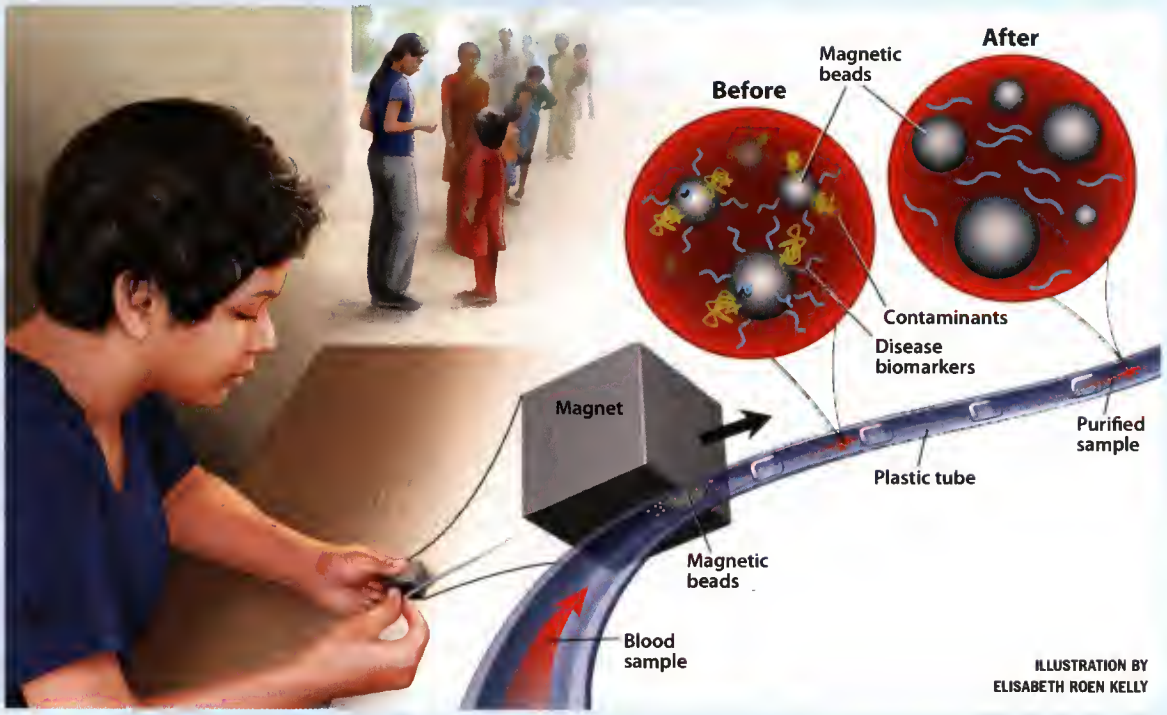

ILLUSTRATION BY ELISABETH ROEN KELLY

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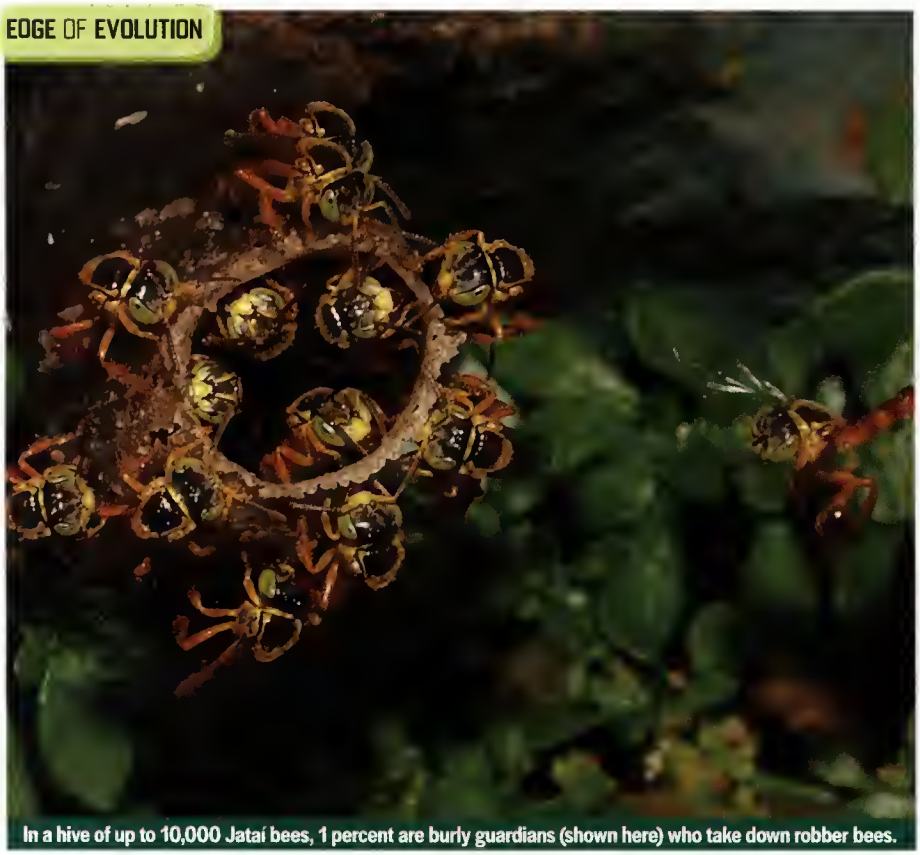
NUMBER

31: The percentage of genetic mutations shared by all the tumor samples taken from a patient with kidney cancer. Doctors often decide how to treat cancer by matching drugs to the mutations that appear in a single biopsy. But when Charles Swanton, an oncologist at the Cancer Research UK Foundation, took 12 biopsies from three of a kidney-cancer patient's tumors, he found that only 40 of the 128 total



In a hive of up to 10,000 Jataí bees, 1 percent are burly guardians (shown here) who take down robber bees.

Bouncer Bees Toss Enemies From the Hive

THE STINGLESS JATAÍ BEE lives in a vicious world where marauding robber bees steal its food and plunder its hive. For protection, Jataí worker bees have evolved a specialized variant: the bouncer bee, a burly guardian with massive legs and a surprisingly small head.

Typically, bees fit into three physically distinct castes. The queen lays eggs; male drones mate with the queen; and female workers guard the nest, collect food, and construct honeycomb. Scientists rarely observed physical differences among workers and widely assumed their size was uniform.

But while studying Jataí in São Paulo, entomologist Cristiano Menezes noticed that the females at the hive entrance looked larger than other workers. Measurements from 12 bee colonies confirmed that. Some Jataí, specialized for guard duty, are 30 percent heavier, with legs about 40 percent larger than those of foragers. Their heads are oddly disproportionate, only 25 percent larger than foragers' noggins.

Guarding is a grisly job made necessary by food raids from *Lestrimelitta limao*, a strong-jawed robber bee. Bouncers chomp down hard on the base of the enemy's wing. But intruders can twist around and decapitate a guard with a powerful bite. "You'll often see a robber bee walking, and on each wing is a separate Jataí mandible," says entomologist Christoph Grueter, who published the work with Menezes. Even when killed, the bouncers prevail: Robbers with Jataí heads on their wings can no longer fly.

JOSIE GARTHWAITE

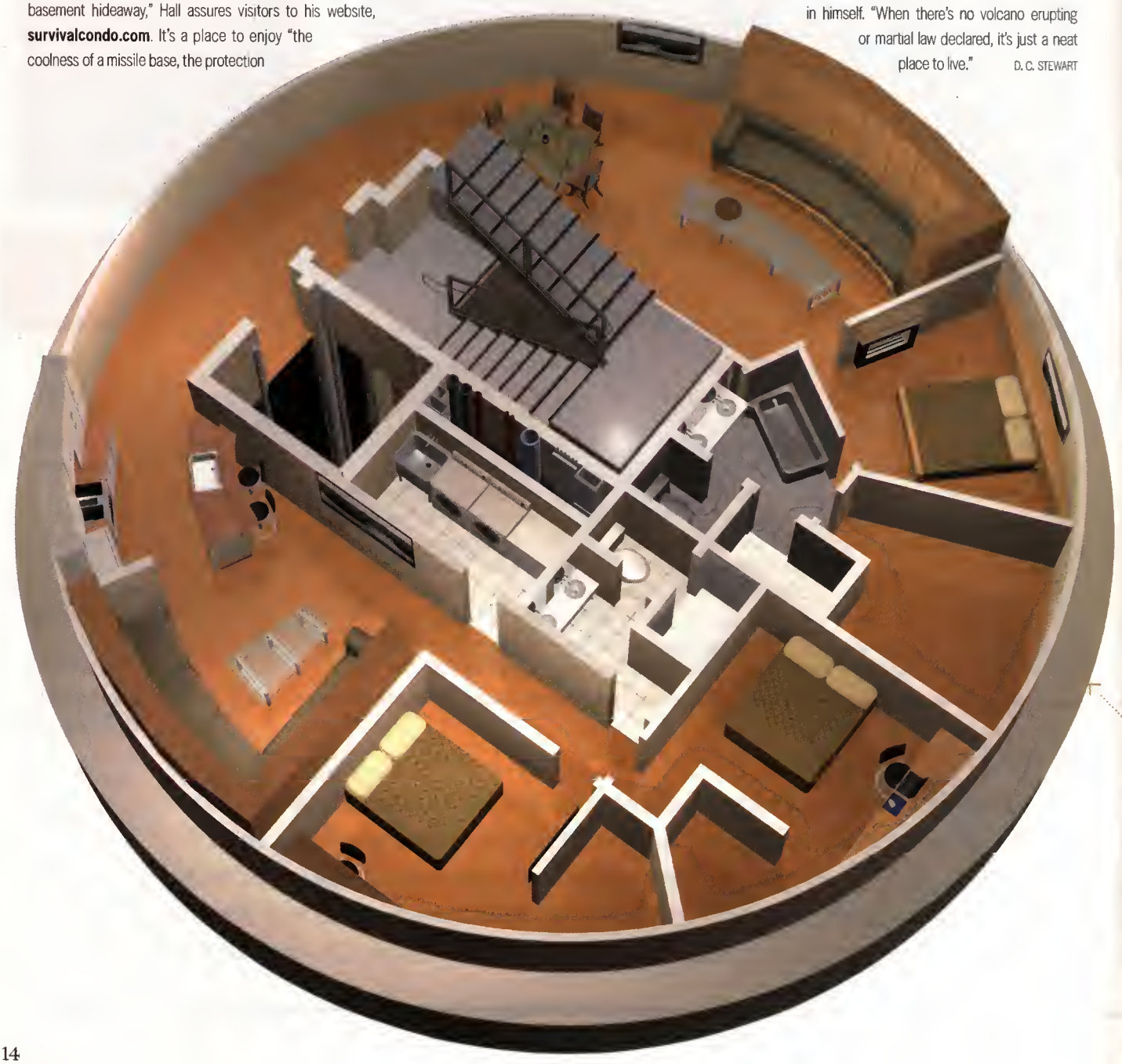
mutations showed up in every sample. The other 88 mutations occurred in some tumor cells but not others. Swanton came up with similar results in three other patients, suggesting that optimum treatment for one region of a tumor might not be effective against another region. "Each biopsy tells a different story," he says. "And that may be why cancer drugs do not work as well as we expect them to." VALERIE ROSS

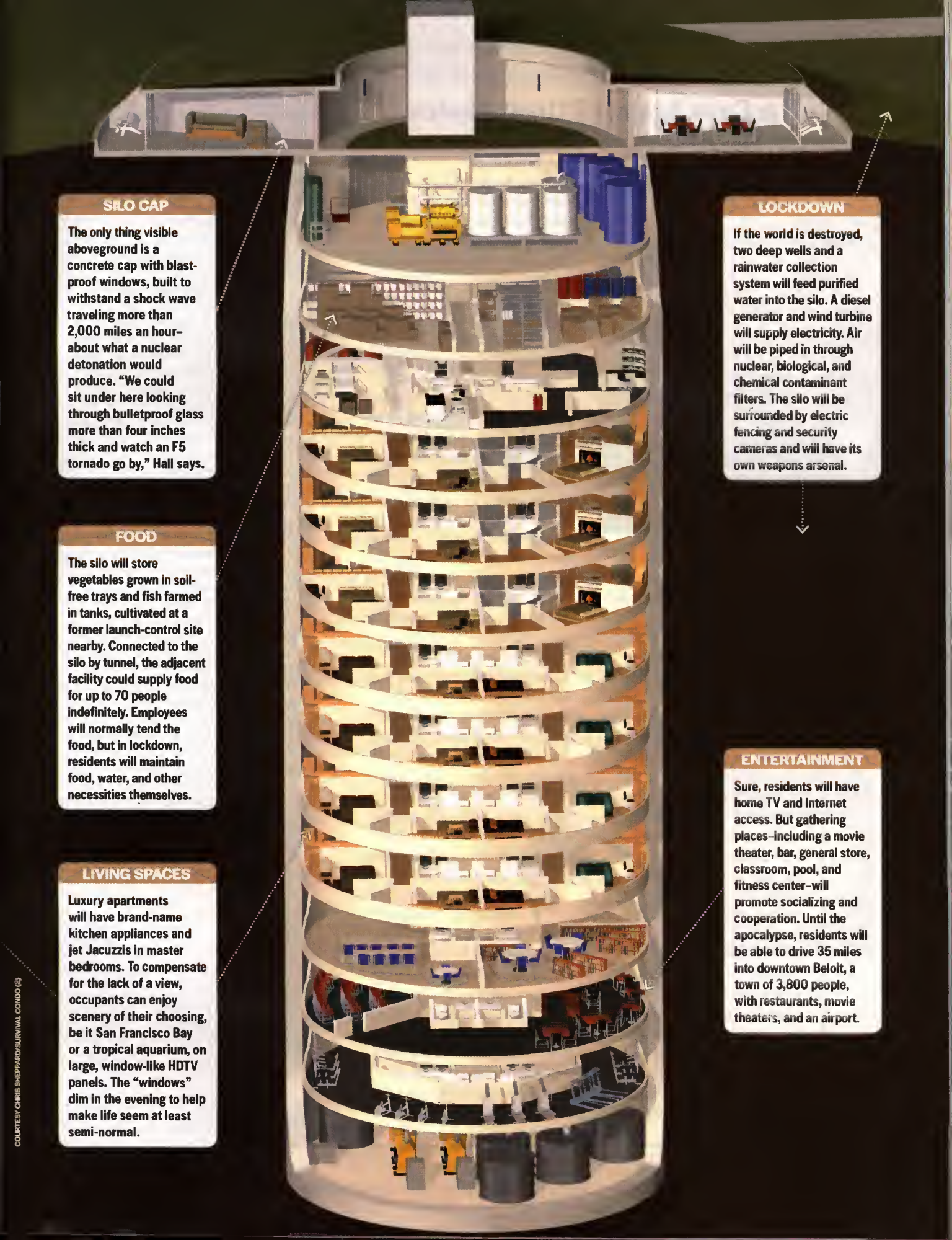
POSTAPOCALYPSE CONDOMINIUMS

Who said you can't ride out the apocalypse in style? An entrepreneur based in Denver is offering wealthy but jittery home buyers a chance to make part of an abandoned missile silo their new home sweet home.

Larry Hall, a former software engineer who bought his 174-foot-deep hole in the ground from the government for $300,000 in 2008, plans to convert it to calamity-proof condos by 2013. The silo is one of 72 built across the country to deter a Soviet attack during the cold war. Tucked into an empty stretch of rural Kansas, it once housed an Atlas F nuclear ballistic missile that could travel more than 7,000 miles. To withstand a Soviet strike, the silo's concrete walls are up to nine feet thick. But it's not some "dreary concrete basement hideaway," Hall assures visitors to his website, **survivalcondo.com**. It's a place to enjoy "the coolness of a missile base, the protection of a nuclear-hardened bunker, and the features of a luxury condo."

Plans include an indoor spa, a movie theater, and a general store that won't charge money-the-purchase price includes five years of food per person. "If you just went to a storeroom and opened cartons for yourself, it'd be kind of depressing," Hall says. This way, residents can enjoy underground living whether or not catastrophe strikes. At press time three 1,820-square-foot floors had sold for $2 million each. Interested parties include a dentist and a former Kansas City Chiefs football player. Should Armageddon break out, up to 70 people might have to live there in lockdown mode for years, so Hall screens buyers for violent felonies, health problems, and anger issues. And he's enthusiastic about settling in himself. "When there's no volcano erupting or martial law declared, it's just a neat place to live." D. C. STEWART





SILO CAP

The only thing visible aboveground is a concrete cap with blast-proof windows, built to withstand a shock wave traveling more than 2,000 miles an hour–about what a nuclear detonation would produce. "We could sit under here looking through bulletproof glass more than four inches thick and watch an F5 tornado go by," Hall says.

FOOD

The silo will store vegetables grown in soil-free trays and fish farmed in tanks, cultivated at a former launch-control site nearby. Connected to the silo by tunnel, the adjacent facility could supply food for up to 70 people indefinitely. Employees will normally tend the food, but in lockdown, residents will maintain food, water, and other necessities themselves.

LIVING SPACES

Luxury apartments will have brand-name kitchen appliances and jet Jacuzzis in master bedrooms. To compensate for the lack of a view, occupants can enjoy scenery of their choosing, be it San Francisco Bay or a tropical aquarium, on large, window-like HDTV panels. The "windows" dim in the evening to help make life seem at least semi-normal.

LOCKDOWN

If the world is destroyed, two deep wells and a rainwater collection system will feed purified water into the silo. A diesel generator and wind turbine will supply electricity. Air will be piped in through nuclear, biological, and chemical contaminant filters. The silo will be surrounded by electric fencing and security cameras and will have its own weapons arsenal.

ENTERTAINMENT

Sure, residents will have home TV and Internet access. But gathering places–including a movie theater, bar, general store, classroom, pool, and fitness center–will promote socializing and cooperation. Until the apocalypse, residents will be able to drive 35 miles into downtown Beloit, a town of 3,800 people, with restaurants, movie theaters, and an airport.

COURTESY CHRIS SHEPPARD/SURVIVAL CONDO (2)

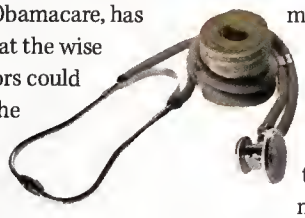
THE CONTRARIAN: Elizabeth DeVita-Raeburn

The Case Against Patient Choice

Limiting options could be good news for grandma.

CONVENTIONAL WISDOM: Top-notch health care depends on preserving a diversity of options and patient choice.
THE CONTRARIAN: Elizabeth DeVita-Raeburn says we need fewer choices and more evidence.

AMERICANS HAVE ALWAYS VALUED the right to make their own choices, especially about health care. So it is not surprising that federal health-care reform, popularly known as Obamacare, has sparked fears that the wise counsel of doctors could be replaced by the rubber stamps of government bureaucrats. The common belief is that only doctors truly know what works and what doesn't.



But the argument falls apart because most doctors lack the evidence to compare various treatments in any absolute way. In 2009 the nongovernmental Institute of Medicine (IOM) released a list of 100 disorders, including lower back pain, atrial fibrillation, and early prostate cancer, that it says require research analyzing which treatments work best for different groups of patients.

Having lots of treatment options is useless if we have no way to intelligently choose between them. That is exactly what we need to remedy in our health-care system: Instead of offering a vast array of choices, we must eliminate options that are needlessly risky and expensive by providing more proof of what works best. The government has pledged $500 million annually, beginning in 2014, to do exactly that. Comparing various treatments and supporting the most effective won't ruthlessly eliminate patient choice. It will help patients and doctors make better treatment decisions. It may end up limiting choice but only by removing the wrong options.

Case in point: a 2007 study in *The New England Journal of Medicine* comparing the long-term effectiveness of treatments for heart-related chest pain. It found that angioplasty, a surgical procedure to open clogged arteries, was no more effective than medication—a far cheaper, less invasive alternative. "It was a gorgeous study," says Harold Sox, an internist who cochaired the IOM report and was not involved in the study. Similar research has recently sorted out treatments for spinal fractures and heart disease.

Funding more of these studies, guided by the IOM recommendations, is critical for strengthening American health care. Patients may like having many choices, but they will love knowing the right one.

OFF THE CHARTS

Largest Map of Dark Matter Across the Cosmos

It isn't easy creating a map of something invisible, but that's what astronomers did earlier this year when they unveiled the largest-ever survey of dark matter.

Astronomers believe dark matter mekes up a quarter of the universe, yet it does not absorb or emit light, and nobody has detected a particle of it. Fortunately, dark matter does reveal itself in a subtle way: As light approaches a clump of the mysterious stuff, it bends around it in a phenomenon known as gravitational lensing. The more massive the clump, the more the light bends. Astrophysicists Catherine Heymans of the University of Edinburgh and Ludovic Van Waerbeke of the University of British Columbia spent five years painstakingly cataloging this lensing in 10 million galaxies with the Canada-France-Hawaii Telescope on Mauna Kea.

Their map, which covers 100 times as much sky as previous surveys, reveals giant heaps of dark matter enveloping galaxies. "Wherever there was a dark matter peak, there was a massive cluster of galaxies," Heymans says. That offers support to the theory that dark matter seeds galaxy formation. Astronomers' next challenge will be matching up the larga-scele map with more detailed studies of visible and invisible matter in galaxy clusters like Abell 520 (below).

Heymans and Van Waerbeke are pressing on with their cosmic cartography. Within three years, after observing 90 million more galaxies, they expect to finish a map 10 times larger. ADAM HADHAZY


Blue denotes dark matter in cluster Abell 520.

CLOCKWISE FROM LEFT: LARRY DOWNING/REUTERS; NASA/ESA/CFHT/CXO/M J. JEE, UNIVERSITY OF CALIFORNIA DAVIS/A. MAHDAVI, SAN FRANCISCO STATE UNIVERSITY; ISTOCK

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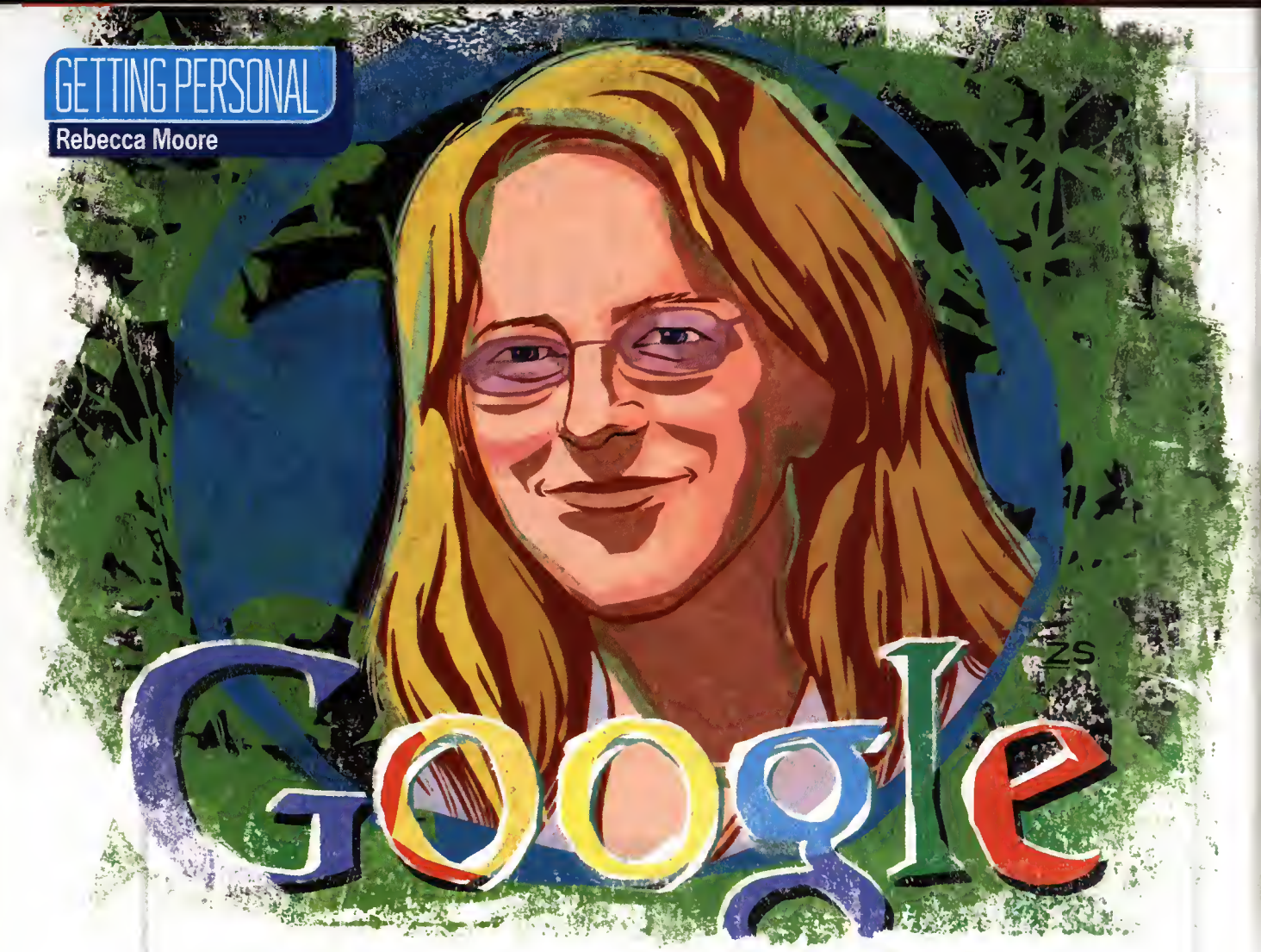

How I Put an Amazon Tribe on the Google Map

Since Rebecca Moore started Google Earth Outreach in 2005, the computer scientist has used her company's satellite-mapping technology to mobilize the public against mountaintop-removal mining in Appalachia and genocide in Darfur. But her most rewarding philanthropic project began in June 2007, when the chief of a small Amazonian tribe walked into her office in Mountain View, California. In her own words, Moore describes the unlikely collaboration that followed and explains how it is paying major dividends for the Surui people of Brazil.

Chief Almir Narayamoga Surui was the first member of his 1,200-member tribe to go to college, and during his studies he discovered Google Earth at an Internet café. Zooming in near his home, he could clearly see that loggers were steadily encroaching on his tribe's 1,000 square miles of lush, green Amazon rainforest. When he returned home, he urged his Surui people to resist illegal logging on their land. In response, the loggers put a $100,000 bounty on his head.

In 2007 a group called the Amazon Conservation Team stepped in to transport Chief Almir to safety in the United States. That's when he requested a meeting at Google to see if we would come teach his people how to put themselves on the map–literally. His idea was to show the world, in a graphic way, what was happening to the forest and its inhabitants. He said it was time to put down the bow and arrow and pick up the laptop, which seemed very Google-y to me.

Over the next year, charitable groups built the Surui a computer center with satellite-based Wi-Fi, and we developed tutorials for people who had never touched a computer. We flew down in 2008 and were greeted with a two-day ceremony. We ate, we danced, and they painted us with tattoos. (At one point, I noticed that my watch had stopped–whether it was the humidity or the shamans, I don't know.) Then we got to work. We taught the Surui how to make Google maps and embed them with blogs, photos, and YouTube videos. Their posts soon drew international attention.

In 2009 we went back with GPS-equipped Android smartphones. Now the Surui could photograph evidence of environmental crimes, put it online, and pressure authorities to enforce the laws. Apps on the phones helped the tribe take inventory of trees and calculate their carbon content.

Now the Surui are using that data to apply for the financial instrument called forest carbon offsets. In many countries, governments and corporations have to meet greenhouse gas reduction targets. Instead of solely cutting their own emissions, these institutions will also be able to pay the Surui to protect their carbon-holding trees. That could earn the tribe $30 million, enough to develop sustainable agriculture and replant 17,000 acres of trees.

What we accomplished together can become a model for tribes in Congo, in Indonesia–anywhere in the world where rainforests are under threat.

AS TOLD TO KENNETH MILLER
ILLUSTRATION BY ZINA SAUNDERS

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What to read, view, and visit this month

Men in Black 3

A decade after their last mission, the alien-wrangling secret agent duo comes back to the big screen. When Agent J (Will Smith) finds that the past has been mysteriously altered and that Agent K (Tommy Lee Jones) has been dead for decades, he travels back in time to rescue his partner and restore history to its proper order. The movie sends J to the summer of 1969, but its by-now familiar buddy-cop dynamic and Will Smith's dated catchphrases have us longing for 1997, when the Men in Black first battled the scum of the universe. *Opens May 25.* SOPHIA LI

SUMMER MOVIE PREVIEW

BATTLESHIP

The U.S. Navy defends the planet against a fleet of marauding aliens in this sci-fi action flick, which features scenes of nonstop nautical mayhem inspired by the eponymous board game. *Opens May 18.*

ABRAHAM LINCOLN: VAMPIRE HUNTER

Your chance to see the 16th president reconceived as an ax-swinging action hero who battles the bloodthirsty hordes that murdered his mother. *Opens June 22.* S. L.

INTERVIEW

DAMON LINDELOF, PRODUCER OF **Prometheus**

***Prometheus*, director Ridley Scott's long-awaited prequel to the *Alien* franchise, hits theaters June 8. DISCOVER editor in chief Corey S. Powell spoke with writer and producer Damon Lindelof (*Star Trek*, *Lost*) about the film, its science-tinged sensibility, and what our own future might look like.**

How was making *Prometheus* different from working on more unbounded sci-fi, like *Star Trek*?

The *Alien* universe is a projected scientific view of the future. If you want to go traveling way off into the galaxy, you have to put yourself in cryosleep because a ship can move

only so fast. In the world of *Star Trek*, you have sci-fi fantasy rules: There is time travel, warp drive, the ability to beam oneself around.

Prometheus, like _Alien_ and Ridley Scott's _Blade Runner_, has strong dystopian elements. Why is so much science fiction pessimistic?

Because the apocalyptic version seems much more probable. The 1960s hung on the promise of the space program. We believed the future was something we could make. But in the 1980s, when I was growing up, that transformed into the idea that the future is something we have no control over. Thirty years from now, nuclear holocaust and artificial intelligence takeover feel much more viable to me than a federation that seeks out new civilizations.

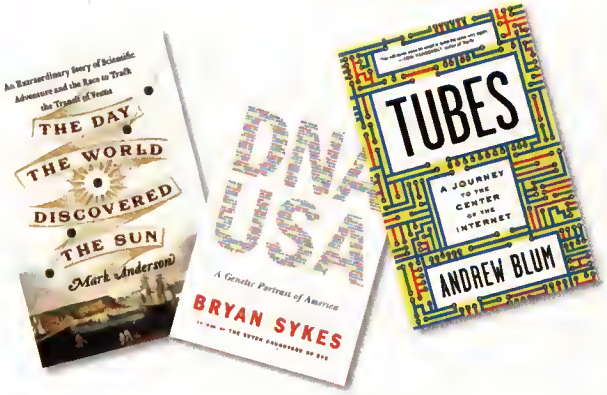
You interviewed futurist Ray Kurzweil about the possible merger between humans and computers. Does that idea resonate with you?

It does. My wife and I have had a number of impassioned debates about what I believe is not a hypothetical question: Would you download your consciousness into a box if it meant you could continue going on? That sounds appealing to me. But the question becomes, what's inside the box? Is it a virtual reality of your own choosing? It gets very daunting very fast.

Despite all its science fiction elements, _Prometheus_ seems like a very human, philosophical story. Is that what you're aiming for?

The jumping-off point for *Prometheus* for me is this: If somebody believed in God and you presented scientific evidence that directly contradicted that belief, what would he do? I find that question tremendously compelling.

BOOKS



THE DAY THE WORLD DISCOVERED THE SUN

By Mark Anderson

Venus's transit across the sun in 1769 gave astronomers their first chance to fix the dimensions of the solar system, a key to mastering global navigation. In this intense account of efforts to measure the rare celestial event, journalist Mark Anderson follows three scientific expeditions to Tahiti, Baja California, and the Arctic. These pioneers sometimes had to abandon science to focus on survival, but at a time when humans couldn't get more than a few feet off the ground, the data they obtained accurately reckoned the distance to the sun at 93 million miles.

ERIC A. POWELL

TUBES *By Andrew Blum*

After a squirrel in his yard gnawed through a vital Internet cable, journalist Andrew Blum set out to track down the structures underlying the Internet's virtual world. He visited vast underground chambers housing network cables and shadowed the network engineers whose job it is to link these parts of the Internet together. Although Blum finds the physical Internet, engineering grandeur aside, often underwhelming, the journey itself and the characters he meets propel the story forward.

VERONIQUE GREENWOOD

DNA USA *By Bryan Sykes*

Oxford geneticist Bryan Sykes has made a career of illuminating Old World migrations and matings, tracing such subjects as the bloodlines of Scottish clans and the ancestry of Ötzi the Iceman. In his new book, he sets his sights across the Atlantic and embarks on a genetic tour of the United States. Since the topic is so wide-ranging, the book jumps frequently across centuries and continents, between personal anecdotes (and Sykes, who does much of his own testing, has many) and scientific analyses. But Sykes's vast knowledge and the bemused enthusiasm of an outsider he brings to the project make him an insightful guide to America's distant, and at times surprising, past.

VALERIE ROSS

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Museum OPEN NOW

MythBusters: The Explosive Exhibition

MUSEUM OF SCIENCE AND INDUSTRY, CHICAGO

***MythBusters*, the Discovery Channel series that uses scientific method to deconstruct and debunk urban legends, is giving museumgoers the chance to join the program's hyperkinetic quest for truth. At a new traveling exhibit based on the show, visitors can conduct hands-on investigations of nearly a dozen myths. To determine whether running in the rain really keeps you drier than walking, visitors sprint or stroll through a 20-foot-long shed that rains down water droplets; results from thousands of soggy visitors will be combined to find the drier method. Or to test whether Clark Kent could really change into Superman so quickly, don a cape and boots in a phone booth-size enclosure (left).**

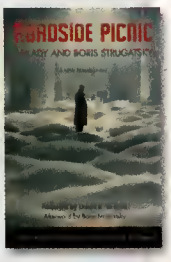
SOPHIA LI

BACK IN PRINT

ROADSIDE PICNIC

By Arkady and Boris Strugatsky

When the Russian Strugatsky brothers published the initial version of their dark novel *Roadside Picnic* in 1972, they marked the vanguard of a new approach to science fiction. Their grim narrative lacked faith in technological progress and celebrated hardened fatalists rather than forward-looking scientists; it also served as the basis for Andrei Tarkovsky's similarly dystopian 1979 film, *Stalker*. Such cynicism is now common in sci-fi, a mainstay of writers like William Gibson (*Neuromancer*) and Orson Scott Card (*Ender's Game*), but the Strugatskys' worldview remains both uniquely cutting and replete with humanity.



Back in print in the United States for the first time in 30 years, *Roadside Picnic* takes place in one of six zones on Earth where aliens once landed and left behind deadly gravitational pits, toxic slime, and technology that researchers risk their lives to obtain and study. The book's main character is a black marketeer who breaks into the zone and pilfers alien objects such as a metal ring that defies the laws of physics and batteries that provide seemingly endless energy. He thinks there is little meaning to be found in the zones, and even the book's scientists have bleak outlooks. One espouses the theory that the visitation was merely one stop on a journey—a roadside picnic—after which the aliens left a mess without taking notice of their surroundings.

The characters' conflicted views of their troubled world make for a read that still feels fresh today. It's also a book that's bound to make you feel a little less sure of humanity's place in the universe. *Available May 1.*

TYGHE TRIMBLE

BY BEVERLY PURDY

Paralyzed by Faith

A Mormon missionary suddenly can't move his legs. What can his doctors do to help him walk again?

THE MEDIVAC HELICOPTER made a noisy descent to the landing pad at University Medical Center in Salt Lake City. The patient on board was on the final leg of a long journey home from South Africa. Jeremy Clark, an ambitious 23-year-old college graduate, had been on a Mormon mission in Johannesburg when he awoke one day unable to move his legs. He was briefly hospitalized there, but the South African doctors could not explain his sudden paralysis and found no evidence of injury or infection, so he was transferred back to the States by air ambulance.

Medics wheeled Jeremy to the neurology ward, where I was waiting. They said he had been about three weeks into his two-year commitment in South Africa when one morning he did not show up for his assignment, nor did he answer his phone. Someone finally went to his apartment and found him lying there, immobilized.

"He's been like this for a week, doctor," the medic told me. "He hasn't spoken since this happened."

The youthful-looking, blond-haired patient stared at the ceiling, his blue eyes unblinking. "Good morning, Jeremy," I said. I felt invisible in the silence. "Are you in pain?"

No reply.

"You're home now," I said. "We'll get to the bottom of this."

As the neurology resident, I needed to test Jeremy for a number of disorders, including multiple sclerosis (MS); myasthenia gravis, a neuromuscular autoimmune disease that causes varying degrees of muscle weakness; Guillain-Barré syndrome, an acute condition associated with progressive muscle weakness and paralysis; and stroke. I would also have to perform a lumbar puncture to collect fluid from around the brain and inside the spinal cord to rule out infection. Although his symptoms didn't quite support the diagnosis, I also wondered if he could have been exposed to a toxin that can cause paralysis, such as botulism or tetanus.

After arranging the tests, I returned with a medical student to assist me with the physical examination.

Jeremy was tall, lean, and physically fit. Heart, lungs, and abdomen: all unremarkable. The neurological examination, however, was perplexing. Cranial nerves were intact. Muscle tone was good, without tremors, abnormal movements, or atrophy. When asked, he was able to move his head, neck, and arms. But his legs were like dead weights, motionless and insensitive to touch.

Even more puzzling, when we tapped Jeremy's leg tendons with a rubber hammer they contracted, a normal involuntary reflex that told us that the nerve path between the muscles and the spinal cord was intact. Another reflex test, designed to detect damage to the nerve pathway through the spinal cord to the brain, was negative.

I discussed the exam findings with the medical student. "The paralysis of both his legs is very strange," I said, "because normally for this to occur, both sides of his brain would have to be damaged, and other parts of his body would be affected."

"Could a stroke do it?" the student asked.

"A stroke would usually paralyze one side. And we can rule out Guillain-Barré since his reflexes are intact and his upper extremities are functioning well."

"What about MS?"

"His history doesn't support that," I said. "There's no evidence of prior episodes of sensory loss or weakness in other muscles. Same with myasthenia gravis."

"So now what?" the student asked.

"We wait for test results."

Looking Beyond Symptoms

The next day, I had just finished reviewing the results when the nurse informed me that Jeremy Clark's parents were waiting to talk to me.

After introductions, I told them: "Jeremy's condition is stable, but he still isn't speaking. Tell me a little bit about him."

Mrs. Clark looked tense. "He's always been healthy. He graduated cum laude and volunteered for this mission. He's a very responsible young man." She glanced at her husband, then at me. "Doctor, what's wrong with our son?"

"The MRIs, lumbar puncture, and lab tests are normal," I said. "That means there's no tumor on his spinal cord or brain, no infection, and his liver, kidneys, and blood counts are fine. That's all good news." I paused. Our tests had ruled out physiological explanations for his problem, but there were other areas to explore. "Does Jeremy use drugs?" I asked.

"Never," Mr. Clark said.

Beverly Purdy is a psychiatrist at Valley Medical Center in San Jose, California. The cases described in Vital Signs are real, but names and certain details have been changed.

"What about mental health problems?"

They exchanged worried looks.

"Are you saying he's faking it?"

"No. The symptoms he's experiencing are real," I said. "We'll figure it out."

"I hope so," Mrs. Clark said.

After they left, I thought about Jeremy. Did he have something to gain by feigning his symptoms? I found his nurse.

"Does he move his legs when he isn't aware we're observing?" I asked.

"No," she said. "We have to rotate him in the bed every few hours to prevent pressure sores."

I nodded. Jeremy had no history of emotional problems, but I still wanted a psychiatric consult.

The staff psychiatrist, an old sage with decades of experience, listened to my account of the steps I'd taken to solve the puzzling case.

"I have a hunch," he said. "Let's go see the patient."

After repeating the neurological exam, the psychiatrist pulled me aside and shot me a meaningful look. "Have you considered conversion disorder?" he asked.

"Considered what?"

He explained that conversion disorder is an unusual psychological malady with symptoms that resemble a neurological disorder or other medical condition. The onset is usually abrupt and typically begins with a mental conflict or emotional crisis, then "converts" to a physical problem that prevents the patient from engaging in the activity that was causing him stress.

The reported prevalence of conversion disorder varies widely from 11 to 500 cases per 100,000 people. More common in women, it can begin at any age but occurs primarily between 11 and 35. Symptoms may include blindness, double vision, paralysis, inability to speak, amnesia, unresponsiveness, and motor tics. Most cases of conversion disorder spontaneously remit within two weeks of hospitalization, but some patients who receive a diagnosis of conversion disorder are later found to be suffering from a physical illness.

MIKE KEPKA/CORBIS

Three percent of Mormon missionaries return home early because of physical or mental health problems.

Probing the Mind for Answers

On the fourth day of Jeremy's hospitalization, I returned to his room, hoping to discover an underlying psychiatric issue. I gave him some Ativan, a mild sedative, then repeated the physical exam while tactfully presenting him the provisional diagnosis of conversion disorder. I reassured him that the tests had indicated his muscles and nerves were functioning normally and that his inability to move his legs was reversible. Finally, I told him his prognosis for recovery was excellent—that his symptoms might improve spontaneously or gradually.

I asked again if he'd been exposed to any chemicals, toxins, or illicit drugs. He made eye contact and slowly shook his head.

"No," he said.

"Has anything been bothering you lately?" I asked.

"I couldn't do it anymore," he said, tearing up. "The mission. I hated being there and didn't like approaching people about religion."

"Why didn't you come home?"

Jeremy's brow furrowed. "I didn't want to let my parents down. And I couldn't break my promise to God."

"Sounds like you were under a lot of stress," I said. We continued to explore his concerns, and I reassured him that no one could force him to go back.

I explained the situation to his parents. Although initially reluctant to accept a psychiatric explanation for his physical symptoms, they agreed to involve themselves in his rehabilitation. After a few family therapy sessions, Jeremy realized they weren't angry and opened up. By the end of the week, with his parents' encouragement and some physical therapy, Jeremy was gingerly walking the halls with them. He was discharged from the hospital and scheduled for follow-up visits with a psychiatrist.

Ten days later, Jeremy had completely recovered from the paralysis.

BY DAVID H. FREEDMAN

Brave New Soaps

Oil spills and toxic waste got you down? High-tech cleansers can scrub our planet as quickly as we can befoul it.

BETWEEN FREAK ARCTIC melting, Japanese nuclear melting, and antibiotic resistance popping up everywhere, I can't help but see the world as tiptoeing into pre-apocalypse. If there is some sort of crapstorm coming and I'm lucky enough to survive it, there's one thing I know for sure: I'm going to need a really good hand-cleaner for the aftermath. When I come in from a hard day of zombie hunting, it won't be just dirt that I'll need to get out from under my fingernails.

Actually, I could use that doomsday soap now—or rather, we all could. That's because most of the human race has no intention of patiently waiting for an unspecified apocalypse and has already gotten a head start on mass despoiling. So far the tides of toxic waste and exploded-oil-rig crude haven't made it as far as my sleepy burb. But right now somebody somewhere is facing a mess that Softsoap won't make a dent in.

Hold that last thought—soap is, in fact, exactly what some of the world's smartest cleanup experts are now touting for the next big spill. You might suppose that scrubbing bubbles would be a poor choice of weapon against giant blobs of crude, especially compared with giant oil-corralling booms and high-tech oil-skimming robots. But soap has some important advantages: It really cleans things up (that's what it is made to do, after all), and at the end, all that oily soap can be neatly and completely gathered up with a magnet.

You didn't know soap was magnetic? You're obviously using one of those old-fashioned iron-free soaps. The new stuff can be found in the laboratory of research chemist Julian Eastoe at the University of Bristol in the U.K. Sure, any numbskull can pour a bag of iron filings into a jug of Tide (trust me, my wife is still screaming). The trick is to get the iron to chemically bond to the soap—or as chemists like to say, the "surfactant"—and in sufficient quantity to enable the ironic solution to be pulled by a magnet.

A Magnetic Mop for Oil

Eastoe played around with a number of surfactants and iron compounds before hitting on solutions of iron salts, related to the surfactants in mouthwash and fabric softeners but with some magnet-friendly metal thrown in. In theory, this soapy slop could be heaved by the tankful onto oily shorelines to mix with the spilled crude, and then sucked up by magnet-equipped vehicles or volunteers, leaving behind none of the toxic solvents or messy detergents commonly employed in cleaning oil. "It would be especially useful for cleaning contaminated seabirds," notes Eastoe, who has obviously never had to wield a magnet against an infuriated, oil-and-soap-covered seagull.

Pennsylvania State University materials science professor T. C. Chung has come up with a different take on an oil-spill cleaner. Chung was working for Exxon in 1989 when that company's notorious *Valdez* tanker spilled 11 million barrels of crude into Alaskan waters. When BP's Deepwater Horizon disaster blackened much of the Gulf of Mexico in 2010, Professor Chung was determined to become Professor Clean. "I saw that in all that time, we still hadn't come up with a better way to clean up oil than a paper towel," he says. "I knew there had to be a solution." That solution, he decided, was Petrogel.

Chung worked with a cheap, plasticlike compound called a polyolefin, a long-chain molecule. Though the stuff isn't technically a surfactant, he chemically tacked on branches to the molecular chain and got it to form a molecular web that surrounds particles of oil. The result: One pound of Petrogel will combine with more than 40 pounds of oil, preventing it from dispersing into the ocean or from sticking to sand or dolphins. "You could spray it on a spill as powder, trap all the oil as gel, and then recover it with skimmers," he says. And since a polyolefin is made up of hydrocarbons, like oil, the easy-to-handle gel could be refined as if it were plain old oil. It wouldn't have to be dumped somewhere, and some of the costs of recovery could be, well, recovered.

The fact that chemically hot-rodded Jell-O and fabric softener turn out to be mighty weapons in the fight against catastrophic soilage might tempt you to rummage through your household items for other potential tools. You need go no further than your pocket or purse, due to the work of a Michigan Technological University chemical engineer who has figured out how to turn chewing gum into another super-spill tamer. Gerard Caneba zeroed in on polyvinyl acetate, a major ingredient of gum. He discovered that this natural, biodegradable stuff needs only a bit of strategic molecular tweaking to become a surfactant that readily foams up in contact with water. "Everyone knows chewing gum is good for making bub-

David H. Freedman is a freelance journalist, author, and longtime contributor to DISCOVER. You can follow him on Twitter at dhfreedman

bles," he says. "It's already pretty close to being a detergent." Oh Bazooka Joe, is there anything you can't do?

The trick to making this gummy soap into an oil-fighter, Caneba found, was to manipulate the compound so that one part of the molecule latches onto water while another part cozies up to crude. The result is a liquid that, when squirted at the edges of a spill, forms a foamy barrier around it that will push the spill in the direction in which the liquid is applied. "If you try squirting water or other liquids at oil, they'll just move around or through it," Caneba says. "This foam will stay up against the oil and herd it." It can even be sprayed upwards via an underwater pipe at the bottom of an underwater plume of spilled oil in order to bring it to the surface. The herding action can keep the oil from dispersing in the water and from reaching shorelines.

If you're still not impressed with the mega-filth-fighting capabilities of this soapy gum, consider that it also works wonders against "red mud," a highly caustic sludge left over from aluminum manufacturing; a recent red-mud spill in Hungary forced hundreds of villagers to evacuate. When Caneba's stuff is sprayed on it, a series of chemical reactions converts the mud into a nontoxic, foamy goo that can be compressed into a durable building material. "It would be great for patio tiles and ceiling insulation," Caneba suggests. I, for one, am completely behind the idea of cleaning the planet while redecorating.

Detox Gels and Foaming Meds

If oily Jell-O cannot mop up your toxic spill, maybe congealed soybean oil can. Building on research conducted at the Savannah River National Laboratory, a company called EOS Remediation in Raleigh, North Carolina, has found a secret ingredient that turns soybean oil into a gel. But here's the interesting part: If you stir it up a bit, it temporarily becomes a liquid that can be pumped into soil that's been contaminated with toxins. Once the liquid is in the soil, it reverts to gel form and stays that way for a long time—years, even. Taking advantage of that long lifetime, EOS laces its gel with toxin-eating bacteria, including one that can break down the chlorinated solvents commonly used to degrease machine parts. The idea is that the bacteria will remain in position for however long it takes to leave the soil squeaky clean—not counting the gel, which is basically edible at the end. It worked for cleaning up a wastewater site at Savannah River, though nobody actually showed up to dine on the end product.

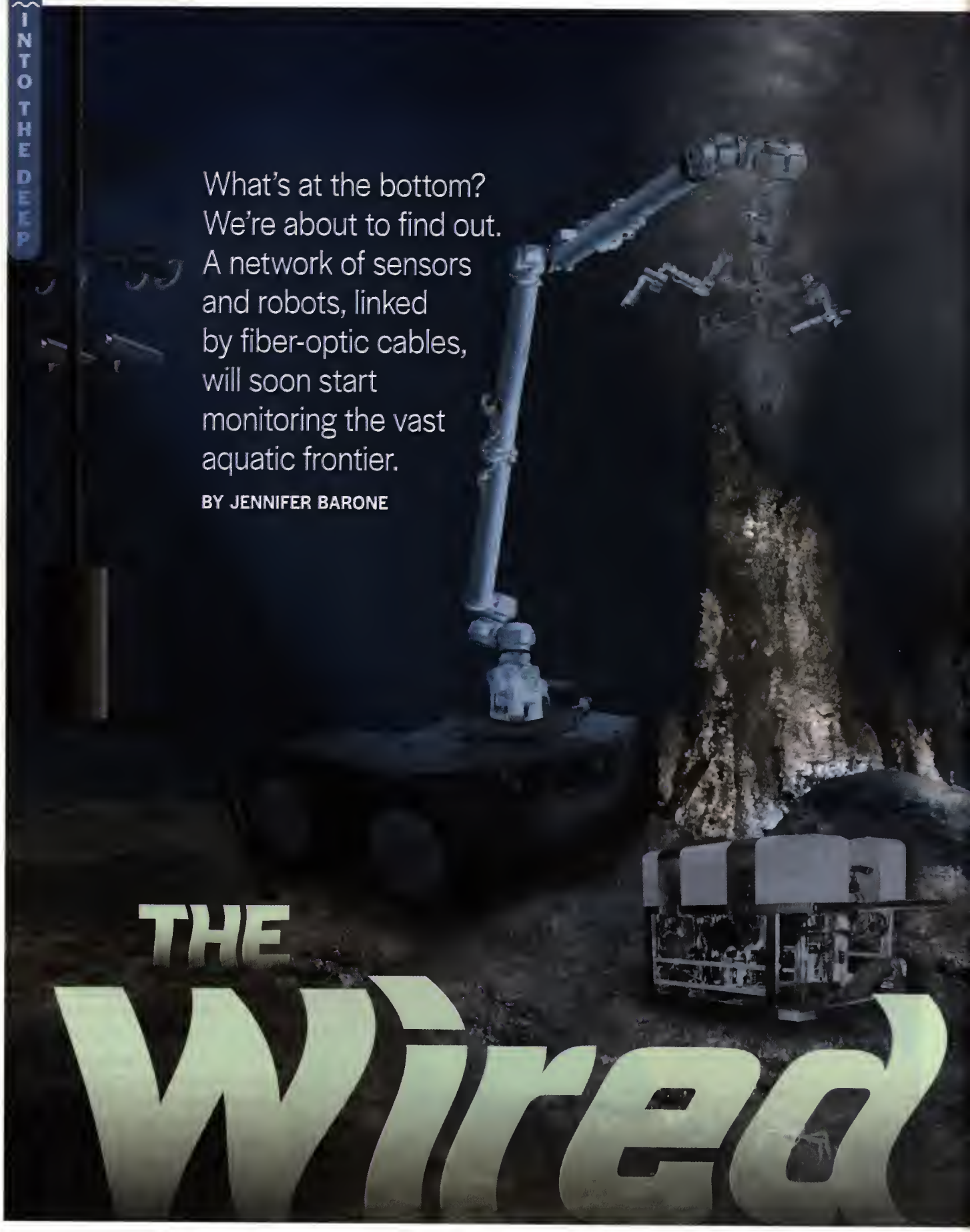
Frankly, I'm doing a huge disservice to soap science by implying that all it can do is save the planet from toxic catastrophes. Eastoe, for example, envisions all kinds of surfactant-based miracles. "The chemical imagination runs wild with the possibilities," he says. True, coming from a soap scientist, you might wonder if "wild" needs to be taken with a grain of sodium chloride. But Eastoe and other chemists are creating genuine supersoaps by finding ways to get surfactant molecules to lose their foamy properties under particular conditions so that the foam can, in effect, be turned off and on at will.

Eastoe has created foams that can be switched on and off with light, so that if mixed with insecticides or herbicides and sprayed on plants, they could foam up only at night or only during the day, whenever they were most effective. He is considering drug-laced foam that could be swallowed by a patient and then de-foamed with an electric field so that it would drop its drug payload only when it's at the right place in the body. And he points out that foam doesn't just clean oil up; it can also produce it cleanly by helping to drag raw crude out of deep deposits.

So inspiring to me is this work that I've started experimenting with other household items to see if I can invent my own supersoap. I've already substantially contributed to the field by brilliantly ruling out organic ketchup and lite chocolate syrup as candidates. Though I have to admit, it's hard to focus with all that screaming in the background.

New-age soaps can respond to light, acidity, temperature, pressure, or magnetism–so they clean up just the right nasty atoms.

ILLUSTRATION BY DAVID PLUNKERT



THE Wired

What's at the bottom? We're about to find out. A network of sensors and robots, linked by fiber-optic cables, will soon start monitoring the vast aquatic frontier.

BY JENNIFER BARONE

SCIENTIFIC CONCEPT BY JOHN DELANEY/UNIVERSITY OF WASHINGTON; GRAPHIC DESIGN BY MARK STOERMER/CENTER FOR ENVIRONMENTAL VISUALIZATION/UNIVERSITY OF WASHINGTON

John Delaney stepped out onto the deck of the *Thomas G. Thompson* shortly before dawn one day last August and paused to look at Puget Sound, an evergreen-lined inlet near Seattle that meanders out to the Pacific. As the ship made its way toward the ocean, he glanced at the white peaks of the Olympic Mountains with a knowing eye. "Those rocks were created on the seafloor, distilled from molten material from the mantle," he said. "They were part of a tectonic plate that got jammed up onto the continent." He watched as the glassy, protected waters of the sound gave way to ripples and sparkling wavelets, hints of the interplay between wind and sea and the currents that course around the globe. He registered the sun on the water and pondered the patterns of energy fueling the blooms of tiny marine plants that nourish an ever-expanding web of life. Every facet of the ocean conjured another, weaving a tapestry so complex he knew he would be studying it for the rest of his life.

To unravel that intricate tangle of relationships, Delaney has envisioned a web of his own: a sprawling undersea network off the coast of Washington and Oregon whose strands of power lines and fiber-optic cables would stretch hundreds of miles along the seafloor, connecting researchers with the ocean like never before. On this expedition, Delaney was setting out to test key components of the system for the first time. And this deep-sea Internet is just one arm of the enormous $770 million Ocean Observatories Initiative (OOI) now under way.

In addition to Delaney's cabled network, the program includes five other sites scattered from the tip of South America to the waters near Greenland, where swarms of instruments will shuttle up and down cables and fly through the water on robots controlled from shore. For decades, sensors will gather data on water chemistry, currents, photosynthesis, animal activity, and seafloor eruptions and earthquakes. When the work is complete, researchers will piece together a systemwide view of the marine environments that cover more than two-thirds of the planet, bringing into focus the interrelationships among the seafloor, the water, and the atmosphere. Does ocean chemistry alter climate? Does undersea geology impact fish populations? Will the web of marine life deliver new energy sources from the sea?

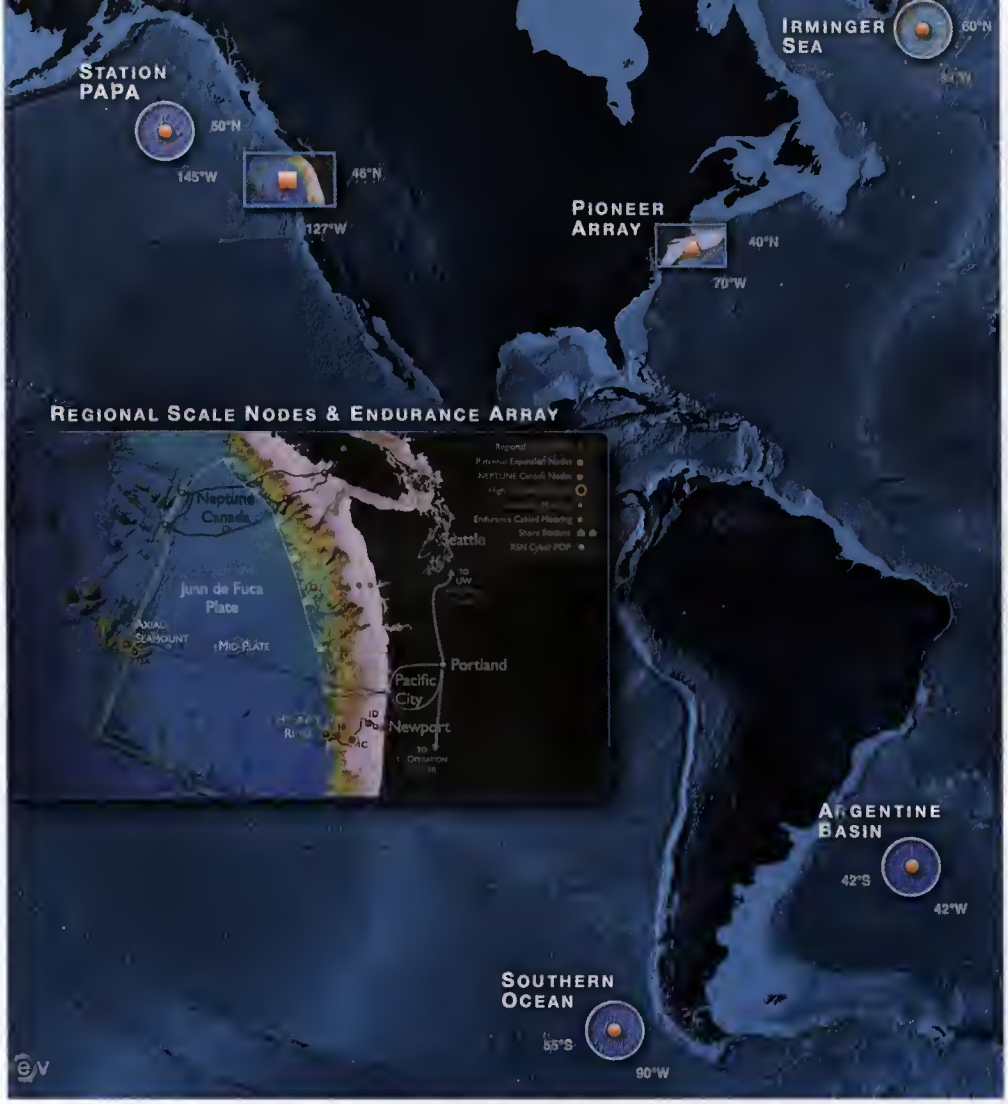
"It's pioneering a way of investigating the ocean," says Timothy Killeen, assistant director for geosciences at the National Science Foundation (NSF). "It will lead to areas of research that we can't even imagine today." For Delaney, that vote of confidence represents both opportunity and pressure. "If this doesn't succeed," he says, "the next time ocean scientists want to tackle something big, we won't get the chance."

Every facet of the ocean conjured another, weaving a tapestry so complex Delaney knew he'd be studying it the rest of his life.

Like so many oversize ambitions, the scheme to build a seafloor Internet took shape in a bar. In 1991 Delaney, an oceanographer at the University of Washington, went out for a drink one evening with Alan Chave, an ocean engineer and marine geophysicist based at the Woods Hole Oceanographic Institution. The two were collaborating on a study of mid-ocean ridges, chains of volcanoes and hydrothermal vents that snake around the planet like the seams on a baseball.

Delaney was griping to Chave that the occasional dive in a submersible just wasn't cutting it for learning how ridge systems worked. Every time he returned to a place, it looked completely different: New lava flows had appeared, vent structures had grown or collapsed, and animal communities had changed, but it was impossible to tell when, how, or why. "It's so frustrating being down there for a few hours at a time," Delaney complained over his drink. "We never have long enough to understand what's going on."

Chave had recently worked at Bell Laboratories, coordinating a project to reuse an old AT&T seafloor telephone cable to transmit undersea earthquake data to researchers onshore in Japan. "Maybe we could use a cable to collect data at a ridge," he suggested. Outfitted with scientific instruments and a video cam-



OCEAN OBSERVATORY sites were selected for depth changes and coastal ecosystems (Pioneer Array); tectonic activity (Juan de Fuca plate); and high latitude (circled sites). Previous pages: Artist's concept of a future seafloor lab.

era, a communications cable would allow Delaney and Chave to watch eruptions on the bottom in real time while safely ensconced in their offices.

The idea seemed a bit outlandish, but over the next several years, the two researchers kept pressing the notion at conferences and meetings, and other scientists chimed in enthusiastically with ideas of their own. On a visit to the Institute of Ocean Sciences in British Columbia, Delaney mentioned undersea networks to physical oceanographer Rick Thomson, who proposed adding acoustic sensors to measure the movement of schools of fish. Biological oceanographer Kendra Daly of the University of South Florida heard a talk by Delaney and excitedly told him that his concept would finally allow researchers to study the ephemeral changes that were so difficult to capture from a ship: a storm churning up the waters below, for instance; or the springtime bloom of microscopic marine plants.

Encouraged by the feedback, Delaney and Chave, along with about 65 other scientists, began to hammer out a proposal in 1998. They would hire industry subcontractors to lay a fiber-optic cable on the ocean bottom. Dotted along its path would be nodes, big boxes of electronics that would serve both as data routers and as power outlets for undersea instruments. A fleet of remote-controlled robotic vehicles would target transient events—for example, gathering gases and microbes released during a seafloor eruption.

As for where to put the network, Delaney and his collaborators suggested the Juan de Fuca tectonic plate, a roughly triangular piece of crust that juts out into the Pacific from the northwest coast. There they would be able to observe several important processes—the formation of new seafloor, volcanic eruptions, the movement of nutrients from deep to shallow waters, and earthquakes.

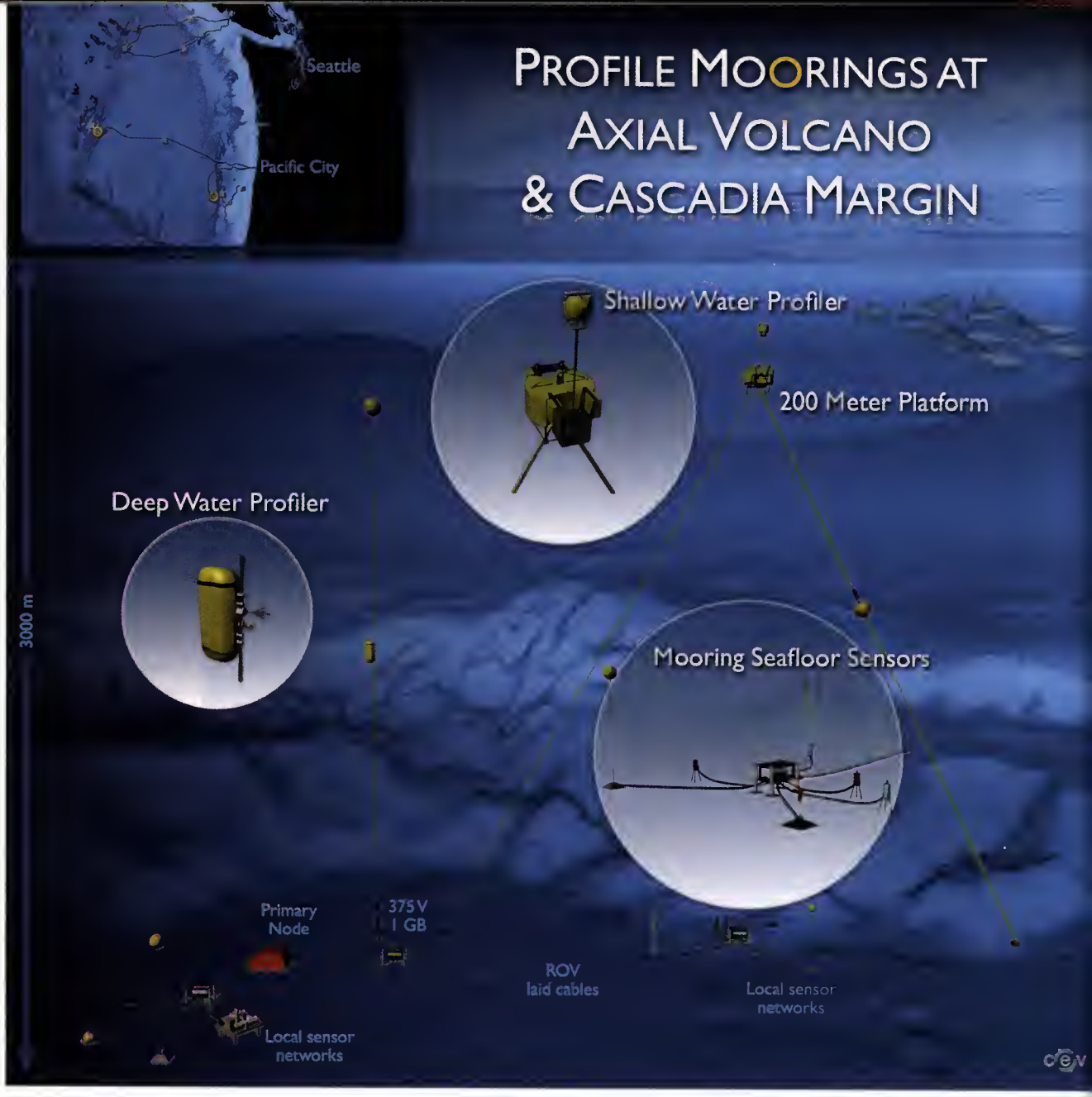
Delaney and his partners targeted two sites on the plate as promising places to install their first instruments. One was Hydrate Ridge, selected for its large methane deposits and the unusual chemosynthetic organisms that thrive on top of them. Methane is a potent greenhouse gas, so scientists are interested in how it might be released from the ocean bottom. It is also the main component of natural gas; the Department of Energy is investigating whether the fuel can be mined from humongous deposits under the seafloor.

The second spot was Axial Seamount, an active underwater volcano, along with its associated hydrothermal vents, where the team could study the transfer of minerals from beneath the seafloor into the water and access hardy microbes that thrive in the vent fluids, which can reach 250 degrees Fahrenheit. During eruptions, they might be able to collect even stranger microorganisms that live in the scorching depths of Earth's crust.

In 2000 Delaney's group submitted the plan to the National Oceanographic Partnership Program, a collaboration of federal agencies involved in ocean research. The idea had the backing of Mike Purdy, then director of ocean sciences at NSF. Purdy had seen firsthand the limitations of existing tools. He knew that ships were great at collecting data from different locations, but when they returned to the same spots a year later, conditions were often wildly altered.

"We need a new approach to understand changes over time," Purdy said. Delaney's cabled observatory addressed that. And bringing power lines from shore would solve the problem of seafloor sensors whose batteries went dead, something Purdy had experienced himself.

OOI REGIONAL SCALE NODES PROGRAM AND CENTER FOR ENVIRONMENTAL VISUALIZATION/UNIVERSITY OF WASHINGTON



ROBOTIC PROFILERS on cables will carry sensors for measuring deep-water salinity, temperature, and currents off the Pacific Northwest; a shallow-water platform will take photos and assess nutrients.

Smaller projects already under way were proving that the deep-sea network concept could work. Scientists at the Monterey Bay Aquarium Research Institute in California had laid a 32-mile cable from shore to a site off the coast, testing power supplies, data cables, and instruments. A team at the University of Victoria in British Columbia had developed a cabled installation to study the physical and chemical properties of the local ocean.

Delaney's proposal would dwarf those projects. Purdy hoped to fund the new ocean observatory through an account that NSF maintains for game-changing scientific infrastructure. But to win approval, the program would have to cover more than just the Pacific Northwest coast. Over nearly a decade, Purdy and his successor, Larry Clark, gathered recommendations from hundreds of researchers on what an ocean observing system should do and which sites would be best to add.

In 2009 the agency settled on a design that included not only Delaney's cabled network at Juan de Fuca but also a wireless, satellite-linked network off Cape Cod to study the transition between shallow continental-shelf waters and the deep ocean, as well as sensor-packed moorings at four sites in high-latitude waters that are rich with aquatic life.

OOI REGIONAL SCALE NODES PROGRAM AND CENTER FOR ENVIRONMENTAL VISUALIZATION/UNIVERSITY OF WASHINGTON

That fall NSF agreed to provide three-quarters of a billion dollars for construction and initial operation of the Ocean Observatories Initiative—a staggering sum in the modest-budget world of ocean exploration. By November Delaney had contracted marine operations company L-3 MariPro to build the backbone of his deep-sea network, including the seven nodes that will power instruments and transmit data through the system.

Finally, in the late spring of last year, the cable-laying vessel *Dependable* began stringing 560 miles of fiber-optic line from Pacific City, Oregon, to Hydrate Ridge and Axial Seamount. A few months later, with cable installation still in progress, Delaney and his team set out from Seattle aboard the *Thompson* to test a node in the water.

Trip to the Ocean Floor

The *Thompson* winds through Puget Sound and then out into the Strait of Juan de Fuca, stopping in Victoria to pick up Ropos, a remotely operated vehicle (ROV) whose motions can be controlled from the ship. The plan is for Ropos to carry a node—a 3,000-pound, yellow and orange watertight box about the size of a refrigerator—to the shallow bottom of the strait to test the plugs and connections that will link it to the cable and to scientific instruments.

The morning is chilly, with fog as impenetrable as the dark waters below. Ropos comes to life on the port-side deck as the vehicle's engineers run their predive check. The robot's camera scans up and down, then side to side. One by one its lights flicker on and off at the command of technicians in the control room.

Crew members lower a titanium cage, which will serve as a protective frame for the node, down to the seafloor. Next Ropos must go down to unhook the wire used to lower the frame and open its doors so that the node can be placed inside. A crane lifts the robot from its cradle. With camera lenses for eyes and mechanical arms folded against its yellow and black body, it looks like a giant insect poised above the water. The crane drops Ropos in. Its lights pop on and diving thrusters kick into gear. Then it disappears into the gray, trailing the umbilical tether that allows it to communicate with the ship.

About 15 scientists and engineers crowd into the dark control room to watch the ROV's video feed. Pilot Reuben Mills navigates Ropos to the frame and begins unscrewing shackles connecting it to the wire, clearing the way for the node. No one speaks. The assembled researchers bite their lips, following Ropos's smallest movements. Its two-fingered mechanical pincer grabs the pin of a shackle in an attempt to undo it, then slips off.

Jonathan Lee, another Ropos pilot, explains that if a sensitive manipulation fails on the first try, the pilot can end up in a "death spiral," overcompensating on every movement due to nerves and sending Ropos's arms in circles around their target. Mills keeps his cool, though, and after a few hours of painstaking work, the frame is ready. Ropos collects the node from the deck and heads back down to insert it into the frame, this time with Lee piloting.

Although the vehicle is returning to the spot it left earlier in the day, strong tidal currents are flowing now, and even with his thrusters at full power, Lee struggles to hold the ROV in place. Delaney unhappily eyes the blizzard of plankton and detritus zooming by on the video feed. "It looks like warp 6 down there," he says. "This could be a serious problem."

On the bottom, visibility fades to a few feet; everything beyond is a swirl of sediment. After a grueling two-hour battle against the current, Ropos reaches the frame. Unable to see clearly, Lee tries to maneuver the node into its slot by feel, without success. The group opts to wait for conditions to improve, but three hours later, the situation is not much better. Ropos operations manager Keith Shepherd slides into the pilot seat for one final attempt and somehow manages to drive the node into its frame. Deciding not to push its luck, the team abandons the remaining tests and hauls its equipment out of the turbulent water.

And that is just one node. Installing seven of them, and connecting them all to the main cable, will be a major undertaking. Delaney estimates that it will take two months at sea to complete the job.

Delaney eyes the blizzard of detritus zooming by on the video feed. "It looks like warp 6 down there," he says. "This could be a problem."

Two days later, the *Thompson* heads over to Hydrate Ridge, 60 miles west of the Oregon coast. There the team plans to test a current meter, which measures water flow. Nearly half a mile down, Ropos's lights pierce the darkness of the bottom, an uneven terrain dotted with rocky outcrops and what look like patches of white snow—sulfur-eating bacteria that form mats on the sediment. Unlike the test site, Hydrate Ridge is too deep to be disturbed by strong currents. Crabs amble slowly across. Purplish hagfish writhe in and out of view, probably searching for a sunken animal corpse to eat.

"So gross," Shepherd shudders. "Don't get buried at sea." Once the seafloor network is operational, these rare glimpses of life on the bottom will be available live on the web.

Ropos drops off the current meter and resurfaces for a second attempt at the node tests that were stymied by the current closer to shore. This time, everything goes flawlessly. The pilots drop the node into its frame and practice plugging and unplugging connectors that will power extension cords and instruments.

The team's next goal is to retrieve an empty instrument frame that engineers put down the previous year to see how it would hold up in seawater—a preview of what the observatory's sensors will endure once they are installed for real. When the frame emerges from the water, strands of algae hang from its surfaces like gray-green hair, but otherwise it is in good condition, with almost no corrosion. Since the engineers plan to bring many instruments up for maintenance once a year, it seems that at Hydrate Ridge their network should be able to operate through its planned life span of 25 to 30 years.

Over the Volcano

Life is rougher at Axial Seamount, where Delaney is headed a week later. The hyperactive undersea volcano continually vents superhot fluids, and magma eruptions occur every 10 to 15 years. Undaunted, Delaney plans to wire that site too, hoping to show how vented minerals accumulate on the seafloor and diffuse into the water above. The

vents host evolutionarily ancient lineages of microorganisms and may have been a cradle supporting early life on the planet.

As a home for sensitive scientific equipment, though, Axial Seamount carries big risks. "It's pretty mind-boggling," says chief systems engineer Chuck McGuire. "We're building this thing worth hundreds of millions of dollars, and we're going to deploy a big part of it—on purpose—in what may be the harshest place on the face of the planet, on top of a volcano."

At a meeting where Delaney and co-chief scientist Deborah Kelley review plans for the site, one researcher asks whether they should rethink the observatory layout in the wake of a recent eruption. "Look," Delaney replies, "if you're going to study an active volcano, you've got to be prepared to lose a few things. We're trying to learn how the lifeblood of the planet works. That means we have to be there."

Instead of trying to protect all of their gear, Delaney says, they will try to identify the safest spots for the nodes, which provide vital power and communications, and then do their best to organize the sensing instruments so that no single eruption can take out everything. Sensors at the volcano and back at Hydrate Ridge will include seismometers, high-def video cameras, temperature and pH sensors, and current meters. The network will also test cutting-edge tools like an underwater mass spectrometer—which can determine the composition of a substance on the spot—and a microbial sampler to sequence DNA on site.

At Axial, the team on the *Thompson* sends Ropos to locate the fiber-optic cable, laid down just a few weeks earlier. Ropos traces the cable's route on the seafloor as Delaney and the others watch the video feed, rotating in shifts, to make sure the cable looks safe, with no sections dangling from rocks or rubbing against rough surfaces. Everything looks fine—except for one segment, which is draped over a previously unknown hydrothermal system. The site is like a hidden city on the seafloor, with sulfide vents towering 120 feet tall, some emitting hot black fluids.

Contractors will replace this portion of the cable this summer, before Delaney's team returns to install all seven nodes, hooking them up to the master cable. Then in 2013 they will plug in their instruments using more than 40 miles of extension cords. By 2014, sensor-carrying robots that climb up and down wires—still under construction—will arrive, completing the initial installation. The other five OOI sites should be up and running by then as well.

"We're building something worth hundreds of millions of dollars, and we're going to deploy a big part of it on top of a volcano."

To Delaney, that is not an end point; it is just the beginning. "We're pushing the envelope with this project," he says, "but we'll be a test bed for future observatories around the world." More than 95 percent of the ocean remains unexplored, and several other countries are already working on parallel programs. Last summer Japan completed a cabled seafloor network called Donet, focused on offshore earthquakes and tsunamis. A cable links 20 sites, each of which hosts seismometers along with pressure sensors that can pick up changes in the shape of the seafloor. Project leader Yoshiyuki Kaneda hopes that such data will provide clues about the build-up of pressure in the crust that leads to large earthquakes.

Other projects share the OOI's broader approach. The European Multidisciplinary Seafloor Observatory program, or EMSO, will install instruments at 12 locations around the continent, from the Arctic to the Black Sea. Like OOI, EMSO will collect a wide range of data, integrating geologic, biological, and climate-change observations. The initial phase of construction will begin at seven sites this year and is projected to be completed by 2016.

Delaney views these projects with a deep sense of urgency. Ocean life does not exist separately from land life any more than the Olympic Mountains are separate from the undersea volcanoes that spawned them. More than half the oxygen we breathe comes from the ocean, much of it from aquatic ecosystems that scientists have barely begun to study.

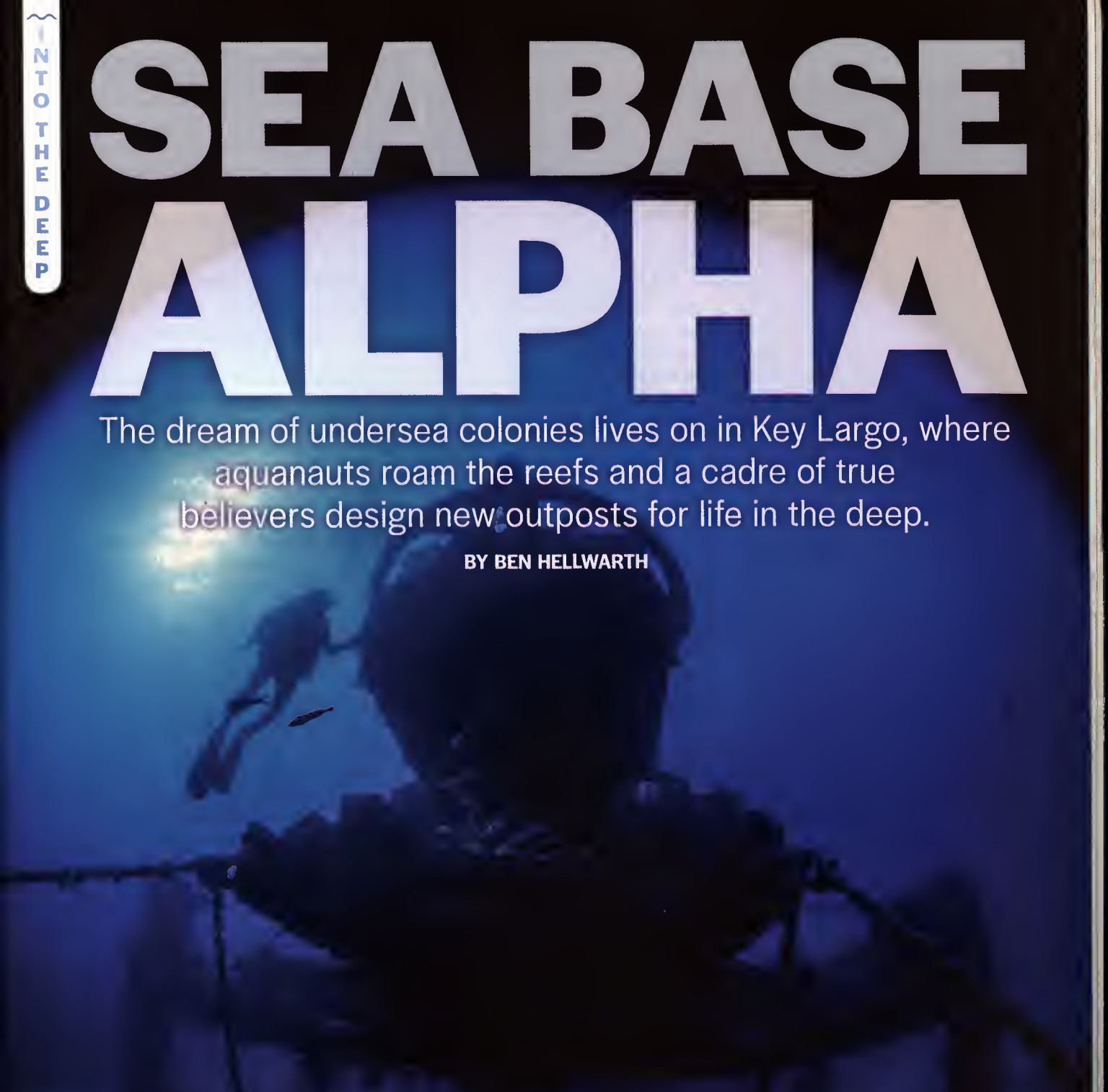
"No one would ever allow a spacecraft to take off if its engineers didn't have a thorough understanding of its life-support system," he says. "We know so little about that system here on Earth, and the ocean is a huge part of it. We have to learn to identify when it might be approaching tipping points, so that we can respond and manage them. We can't do that yet. We're not wise enough. But this is a step in the right direction."

Jennifer Barone is senior associate editor at DISCOVER.

SEA BASE ALPHA

The dream of undersea colonies lives on in Key Largo, where aquanauts roam the reefs and a cadre of true believers design new outposts for life in the deep.

BY BEN HELLWARTH



D.J. KELLER/LIQUID PICTURES 3D

IF THERE IS ANY PLACE ON EARTH YOU MIGHT EXPECT TO FIND them—the true believers in the imminent coming of manned undersea outposts or spectacular domed colonies on the ocean floor—it would be here, in Key Largo. This first major stop along the 100-mile Overseas Highway to Key West is home to the world's only underwater hotel, the only continuously operating underwater lab and classroom, and the only undersea research base. And it is in Key Largo that you find divers like Ian Koblick, whose even tan hints at his lifetime of outdoor ventures. His hair and trademark goatee are graying, although for a septuagenarian he looks as if he takes regular dips in the Fountain of Youth. Like so many others along this steamy island chain, he's wearing shorts and a billowing Hawaiian shirt. No matter that he is seated behind a large desk in the kind of high-backed executive chair more often associated with Brooks Brothers.

The wood-paneled walls around Koblick's office are filled with memorabilia that attest to his years as an undersea pioneer and a genuine player in a decades-long quest to turn ordinary divers into "aquanauts," the name applied to those equipped to live on the seabed, much as crews launched into space get to be called astronauts.

oblick was among the early converts to the concept of undersea living when it came of age in the 1960s, in the shadow of the momentous achievements of the race to the moon. But the nascent quest to equip aquanauts to live in "inner space," as some called the vast undersea realm, never got anything close to the billions of dollars pumped into launching the Apollo astronauts into outer space, birthing an industry and defining the global zeitgeist.

Koblick's early brush with official indifference convinced him that the government would never support an undersea corollary to the space program. So he went looking for entrepreneurial solutions to creating underwater habitats: school bus–size seafloor shelters that give aquanauts a pressurized, climate-controlled base, just as the International Space Station gives astronauts a hospitable home in orbit.

A prominent example of such a habitat, called Jules' Undersea Lodge, lies a stone's throw from his office, submerged in a lagoon that juts like a cul-de-sac into Key Largo Undersea Park. Part tourist destination and part science center, the park has a homegrown feel and a touch of that easygoing kitsch that seems to permeate the Florida Keys. How Jules' Lodge—once a state-of-the-art, research-oriented seafloor habitat of Koblick's design—came to be a novelty underwater hotel in a lagoon says a lot about the struggle to keep the concept of manned sea dwellings alive.

Koblick may sound like a romantic dreamer for his enduring belief in the value of seabed habitats and his persistent efforts, over many years, to create new ones. But he is not alone. Just a couple of miles from Koblick's office along the Overseas Highway, you'll find a cadre of believers, a dozen or two of them, depending on the day. They work out of a pair of canalfront houses whose interiors have been transformed over the years into mission control for the world's only surviving full-fledged sea base, called Aquarius. Owned by the National Oceanic and Atmospheric Administration (NOAA), Aquarius has spent more than two decades perched out on a reef 60 feet below the surface and 9 miles from shore, serving as a scientific research base in the Florida Keys National Marine Sanctuary. The combined activities of this public, science-oriented habitat and Koblick's private Undersea Park make Key Largo the kind of mecca where aquatic dreams live on.

THE ONLY SURVIVING SEA BASE ON EARTH, AQUARIUS IS SUBMERGED 60 FEET UNDERWATER ON A REEF OFF THE FLORIDA KEYS.

UNTIL JUST HALF A CENTURY AGO, the idea of housing human divers on the seabed was pure science fiction. Even with the advent of modern scuba in the 1940s, strict depth and time limits were inevitable because of the physiological effects that come from breathing underwater and under pressure. In order to avoid painful internal injuries and even death, typical dives to modest depths of, say, up to 100 feet lasted only minutes, not the days or weeks that would be necessary to live and work out of a seafloor habitat.

Then, in the late 1950s, a genial, charismatic U.S. Navy doctor named George Bond, who had been trained as a diver, caused a stir by questioning the conventional diving limits. Despite resistance from Navy skeptics, Bond began a series of experiments at the Navy's submarine base at New London, Connecticut, where he was in charge of the medical research lab. Much as NASA used simulators to test dogs and monkeys before launching them into space to gauge the physiological effects of g-forces and weightlessness, Bond sealed animals, and eventually human volunteers, in pressurized tanks to simulate a deep-sea habitat. Instead of weightlessness, the aquanaut would have to endure, among other things, artificial atmospheres with gaseous mixtures different from what we breathe on land, maintained at significantly higher pressures than those at sea level to match the water pressure at depth. One problem is that when divers descend more than about 130 feet, customary levels of nitrogen (78 percent of air on the surface) have a narcotic effect. Bond found that helium proved a suitable replacement on long-duration dives. Oxygen, making up 21 percent of the air at sea level, can cause convulsions and death if pressure gets too high, so oxygen had to be progressively reduced with every foot of descent, and then slowly raised as a diver came back up.

In making these adjustments, Bond and his team were testing a concept known as saturation diving, which turned out to be the key to prolonged stays underwater and under pressure. Much as a sponge absorbs liquids, bodies absorb gases through the process of respiration. A body becomes "saturated" as the gases a person breathes disperse into the blood and tissues. At greater depths, a diver has to breathe higher-pressure gases so his lungs are not crushed by his higher-pressure surroundings. As pressure goes up, so does saturation, like a dry kitchen sponge absorbing more liquid the longer it's held underwater. Once a diver was saturated with the right gases for a given depth and pressure (a process that took a day), he could safely remain at that depth indefinitely. The finding was a revolutionary advance that changed what could be done on the seafloor—provided, of course, that divers, once saturated, had a properly equipped, pressurized habitat as a dry shelter. No one had ever built such a thing.

Favorable results from Bond's lab compelled Jacques Cousteau and the American inventor Ed Link to jump into the Mediterranean with small ocean habitats in the fall of 1962, just a few months after the first orbital spaceflights. Link's prototype wasn't much larger than a phone booth, with room for just one diver. Cousteau's was little more than a cylindrical tank, shorter than a school bus but with beds and amenities enough to accommodate two aquanauts for a week. These and the other early underwater habitats had dry interiors, pressurized to match the water pressure outside. That meant a hatch in the floor could remain open without the sea rushing in, and the aquanauts living inside had ready access to the sea outside at any time of day or night. By 1964 the Navy had launched Sealab I, 40 feet long and 9 feet in diameter. Equipped like a camper, it had bunks, galley, toilet, shower, and a hole in the floor so that four aquanauts could come and go.

The first Sealab aquanauts were deployed to the seabed southwest of Bermuda for 10 days at a depth of nearly 200 feet. They demonstrated the ability to spend hours in the water and work outside the habitat, all while undergoing physiological testing to make sure they weren't killing themselves by living in this alien environment.

WHILE ALL THIS WAS GOING ON, Koblick was graduating from college in California and setting his sights on a graduate program in marine biology. His interests led him to become an early devotee of scuba, the perfect tool for gathering fresh seaweed samples offshore from Monterey, where he had an internship at Stanford University's Hopkins Marine Station. That experience convinced him that to truly know the ocean, a scientist had to work in the ocean—or better yet, live in it just as Jane Goodall lived in the jungle to study chimps. He felt so strongly that he turned down a scholarship to Duke University, putting off graduate school and moving

Jules' Undersea Lodge: A postcard from the 1980s (left) and a patron awaiting dinner (above). On page 33: a marine scientist explores near the still-active sea base Aquarius in the Keys.

JULES' UNDERSEA LODGE (2)

with his wife and young son to the Virgin Islands, where the seawater would be warmer than at Monterey. He soon landed a job at the newly formed Caribbean Research Institute and took the lead in establishing an ecological research station at Lameshur Bay on St. John.

Koblick's timing was perfect: A second Sealab trial came in the summer of 1965, this one located off the coast of San Diego. The new habitat, looking like a cross between a submarine and a railway tank car, accommodated three separate teams of 10 aquanauts for two weeks each. It was followed a few years later by the 60-foot-long, cylindrical Sealab III, which was designed so a dozen aquanauts at a time could conduct experiments at a depth of 600 feet, a giant leap out onto the continental shelf.

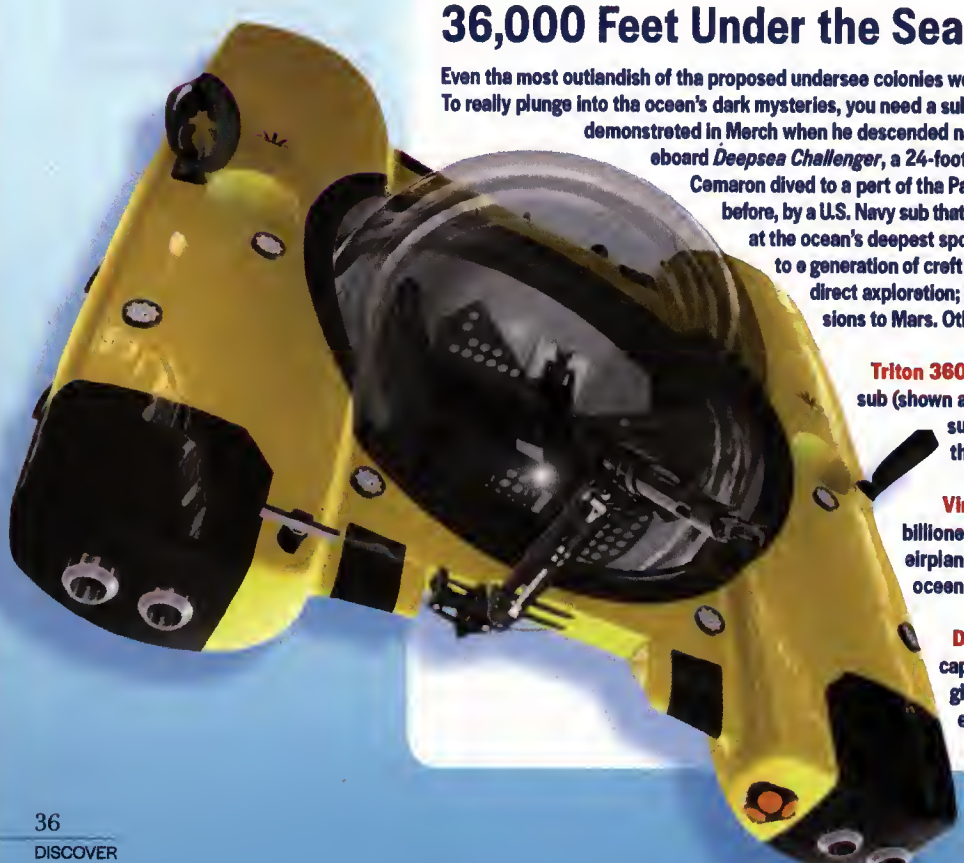
When a delegation from Washington, D.C., came to scope out the Virgin Islands as a possible site for a new, still more advanced habitat, it was as if the candy store had come straight to the kid. Koblick saw his chance to become an aquanaut. He eagerly led the sales pitch, showing visiting representatives everything he could think of—including a sampling of the tasty, cheap local rum—to convince them that the waters around the Virgin Islands would be ideal for their prototype. He called it Tektite, for meteors that survive their fall through the atmosphere, crashing into the ocean and leaving pearl-like fields of debris along the seafloor.

The pitch paid off. Tektite, jointly funded by the Office of Naval Research, NASA, the Department of the Interior, and General Electric, the habitat's builder, was approved and placed in Lameshur Bay. Whereas Sealab had a military orientation, Tektite focused on marine biology and geology, and on duration more than depth. NASA's interest was in the psychological lessons that might be gleaned from observing people living in cramped quarters in a hostile environment—conditions similar to long-duration spaceflights. Instead of a more common horizontal tank, Tektite had side-by-side vertical tanks, each about 12 feet in diameter and two stories tall, that were mounted on a rectangular base, like upside-down bell jars on a shoe box. Four divers from the Department of the Interior were selected as aquanauts, but Koblick had argued for a few alternate aquanauts—just in case—and he was soon off to Washington and Philadelphia for physical tests and training to be one of them.

Tektite's inaugural mission began in February

36,000 Feet Under the Sea

Even the most outlandish of the proposed undersea colonies would sit just a few hundred feet below the waves. To really plunge into the ocean's dark mysteries, you need a submersible—as director James Cameron spectacularly demonstrated in March when he descended nearly seven miles (35,756 feet, to be exact) aboard *Deepsea Challenger*, a 24-foot vessel equipped with a robotic sampling arm. Cameron dived to a part of the Pacific's Mariana Trench that was visited just once before, by a U.S. Navy sub that spent 20 minutes there in 1960. Cameron stayed at the ocean's deepest spot for three hours. *Deepsea Challenger* belongs to a generation of craft that are opening the ocean's extreme depths to direct exploration; if sea colonies are space stations, these are missions to Mars. Other players in the seven-mile-deep club:



Triton 36000, the world's deepest-diving multipassenger sub (shown at left). Built by Triton Submarines around a superstrong glass sphere, it can carry a crew of three to a depth of seven miles in 75 minutes.

Virgin Oceanic, a one-person sub backed by billionaire adventurer Richard Branson. The vessel uses airplanelike wings to "fly" across the bottom of the ocean for distances of up to six miles.

Deepsearch, designed by DOER Marine, will be capable of eight-hour missions, giving marine biologists a chance to perform extended field studies of extremely deep aquatic life. ERIC A. POWELL

COURTESY TRITON SUBMARINES. OPPOSITE: ODER MARINE

1969. The habitat's depth was about 45 feet, a fraction of the 600 feet or more that Sealab had been aiming for—so less complexity was needed for the pressurized gas recipe and the aquanauts' eventual decompression. But the 60-day mission there set a duration record and marked another significant step in undersea habitation. As an alternate aquanaut, Koblick did not get to stay inside the habitat but was in the water every day to help carry out Tektite science projects, especially chasing down lobsters to attach color-coded tracking tags. Though the narrow focus was lobster biology, Tektite's overarching mission was exploring just how marine research might most effectively be carried out from a seafloor base.

When Tektite came to a successful end, Koblick was appointed special assistant to the governor of the Virgin Islands for undersea programs and immediately started lobbying the Interior Department to get a chunk of the money needed to bring the Tektite habitat back to the same spot.

TO TRULY UNDERSTAND THE OCEAN, A SCIENTIST HAD TO LIVE IN IT–JUST AS JANE GOODALL LIVED IN THE JUNGLE TO STUDY CHIMPS.

It took some doing, but a year later Tektite II was launched. This time Koblick got his wish: a shot at being a bona fide aquanaut who lived under the sea. For three weeks he and others on the crew set up beacons outside lobster dens, part of a signaling system that alerted them whenever lobsters were on the move. To Koblick it felt as though they were firefighters, leaping into action at the sound of the alarm. Over the weeks of residence, they also studied the fluctuations and migrations of planktonic organisms in the water column, still a focus of research today. Tektite II operated successfully for seven months, through the fall of 1970, housing a total of 53 marine scientists.

THE TEKTITE II PROJECT had been so costly that there would be no Tektite III. But soon after, Koblick and his newly formed nonprofit, the Marine Resources Development Foundation, approached the Puerto Rican government with an idea of his own. Could he help them launch a similar habitat program to size up offshore resources and inventory sea life on nearby reefs? That's how a new and improved habitat—whimsically called La Chalupa, Spanish for a type of fishing boat with a tendency to capsize—got its start.

While most habitats had a tanklike appearance, La Chalupa looked more like a barge, about 50 feet long, 20 feet wide, and 10 feet tall. Its hollow interior contained two adjoining cylindrical chambers that could be sealed and pressurized as living quarters. A ballast system took in and released water to help sink and raise the habitat, which was designed for easy towing. It could house up to five aquanauts at a time for two weeks, at depths ranging from 50 to 106 feet.

Project Deepsearch sub: Designed by marine consulting firm DOER, it will reduce transit times to the deepest parts of the ocean and provide an expansive view.

On one of La Chalupa's first missions, in 1972, scientist-aquanauts surveyed nutrients and bottom sediments and described algal populations, identifying some 30 new species. On a later mission they collected fish to determine their food sources. They studied the behavior of reef fishes and fish parasites, as well as coral's ability to slough off silt that could drift in from nearby dredging operations. They also tested a saturated aquanaut's ability to reach depths down to 300 feet, extending the possibilities for exploring from a habitat placed at 100 feet. Koblick himself was a Chalupa aquanaut in the spring of 1974 when his mission almost came to a tragic end.

KOBLICK AND HIS DIVE BUDDY, Al Waterfield, a research diver from the University of New Hampshire, were 150 yards from La Chalupa unspooling a transect line, a cord to keep track of their whereabouts. Koblick was wearing a closed-cycle rebreather—a complex piece of gear that could supply breathing gas for longer periods in dives to 300 feet. He took a breath at one point and also sucked in some water: The gear had sprung a leak. To make matters worse, the water was laced with the chemical compound the rebreather used to absorb carbon dioxide, causing a burning sensation in his mouth and throat.

Koblick gave an emergency signal to Waterfield, who went to get help. Meanwhile, Koblick used the transect line like a handrail to pull himself along the seabed, but he felt that the ocean was closing in on him. The coral in his peripheral vision began to blur. His field of vision narrowed, as if he were looking through a telescope. Before long all he could see were his hands grasping the line in front of him. "Mother Ocean, you are not going to get me," he said to himself, just before coming over

a rise, the habitat no more than 20 yards away. Then he passed out. Next thing he knew, he was getting slapped in the face. His fellow aquanauts had managed to drag him up through the entry hatch in the floor of La Chalupa and resuscitate him. He sputtered and coughed up water. His throat still burned and he developed a painful ear infection, but he was alive.

Before the mission was over, Koblick and the Chalupa crew were struck anew by their front-row view of the dynamic undersea environment. The four aquanauts were lying in their bunks, looking out a port window as big around as a manhole cover, sipping rum and Cokes—the soda was flat because of their pressurized surroundings. A smattering of small fish and crabs mingled outside on a grassy patch of sand. A gurnard fish entered the scene, using its winged pectoral fins to cruise along the bottom. Out of nowhere a fish the size of an overstuffed golf bag appeared—some kind of snapper, perhaps, though no one was sure. It hovered near the gurnard, moved in, and—slurp!—sucked it up like a vacuum cleaner, leaving a puff of sand. The big fish started to swim off, then stopped and spit out the gurnard, which hastily swam away.

A FISH THE SIZE OF AN OVERSTUFFED GOLF BAG APPEARED, HOVERED NEAR THE GURNARD, MOVED IN, AND–SLURP!–SUCKED IT UP LIKE A VACUUM CLEANER.

Koblick hoped La Chalupa would open a deep-sea vista for more scientists, but when the Puerto Rican missions ended in the mid-1970s after a new round of funding cuts, he could find no other takers for his state-of-the-art habitat. So he towed it back to Florida, where it languished for almost a decade, until his foundation converted it into Jules' Undersea Lodge—named for Jules Verne, of course. It's like a cozy cabin that sleeps up to six, in considerable comfort, and has been doing so since the mid-1980s, when it was placed in Emerald Lagoon, in about 30 feet of water at Key Largo Undersea Park. Koblick co-owns and operates the park with his longtime business partner, Neil Monney, a former professor and director of ocean engineering at the U.S. Naval Academy. The two met during Tektite, and Monney later signed on as a Chalupa aquanaut. While teaching at the Naval Academy he instigated the small tank of a classroom called MarineLab, which is next door to Jules' Undersea Lodge in the lagoon. With Jules' Lodge and MarineLab, the two partners could continue to offer a window into the underwater world and provide a taste of the freedom that comes from having an open hatch in the floor.

The habitat movement might have stalled there, but the National Oceanic and Atmospheric Administration had Aquarius built in Victoria, Texas, in 1986. At 43 feet in length, the tanklike Aquarius, dispatched to the Virgin Islands, could accommodate six aquanauts to depths of 120 feet. But after hurricane Hugo walloped the islands in 1989, Aquarius was moved to the Florida Keys. Its current assignment in the Florida Keys National Marine Sanctuary enables study of the third-largest living coral barrier reef system in the world.

IT WAS TYPICALLY WARM in Key Largo last August as staffers prepared to cruise out to Aquarius aboard the *George F. Bond*, NOAA's 46-foot research boat that's named for the father of Sealab. They were about to meet up with researchers who, nine days earlier, had jumped off the stern of the *Bond* and swum the 45 feet down to where they could enter the habitat through its "wet porch," a water-filled foyer the size of a Jacuzzi. Team leader Chris Martens, a marine biologist at the University of North Carolina at Chapel Hill, had lived and worked out of Aquarius a half-dozen times before. So had his coinvestigator, Niels Lindquist, a UNC marine scientist. Now they were using their days in Aquarius to zero in on the causes of ocean acidification, which may be contributing to the degradation of coral reefs. Of particular interest: whether some acidification might be caused by respiration of bottom-dwelling creatures like sponges, or whether most can be attributed to

Challenger Station: Atlantica Expeditions hopes to deploy this hub by 2014 as the first module of an expanding undersea community.

BRENT HARTWIG. OPPOSITE: AP PHOTO

carbon emissions from an industrialized world.

Using more than a dozen instruments placed around the habitat, including a first-of-its-kind underwater mass spectrometer that tracks fluctuations in key gases up and down the ocean waters, aquanauts watch readouts in real time on computer screens. When alerted to interesting changes on the reef, they quickly gear up and swim out, like Koblick in the lobster-tracking days of yore, to supplement that information with their own firsthand reports. Through this combination of instrumentation and on-site measurements, the scientists are putting together a more precise picture than ever before of what's happening on Conch Reef, as the Aquarius site is known.

"The habitat allows you to become part of the surroundings," says Martens, echoing Koblick almost word for word. "You watch twilight come, nighttime, you see things happening, you understand what's going on. It allows you to go out the next morning and ask the next question, because you're looking for something new. It's an immersion kind of thing."

But sending down human explorers instead of using robot submersibles brings pitfalls and risks. Stings around Martens's face and neck attest to attacks from jellyfish, noticeably more abundant on this mission, and a curse but in some ways a blessing as well. The surge in moon jellies might be fodder for a future mission, and yet another research paper on top of the 300 Aquarius has already spawned in top-notch journals—assuming the missions can go on. That has been in question since 2009, when a diver was returning alone to the habitat from a work site about a hundred yards away. Something went wrong with his breathing gear and, just as Koblick did during that close call outside La Chalupa, he passed out. But by the time the stricken Aquarius diver could be hauled back to the habitat, he was already dead. On top of that are the national pressures to slash government spending. Aquarius must compete with other NOAA programs for a slice of the agency's annual budget of about $5.1 billion, most of it devoted to weather and satellite studies.

"We are very precariously near the tipping point of losing Aquarius," says former congressman Brian Baird, who represented southwestern Washington State for a dozen years until January 2011 and served on the House Committee on Science and Technology. "If I had to bet, I'd say it's very possible we do lose Aquarius, and I think that would be such a shame."

The situation echoes Koblick's frustration of years ago, when Tektite was stymied by governmental ambivalence. Yet four decades later, the Key Largo dreamers are still at it, seeking a formula for dwellings on the ocean floor. Tourism is one recurring theme. Former congressman Baird likes the idea of a government-sponsored habitat that would be open to the public, with user fees defraying costs as in national parks. Submersible builder L. Bruce Jones is forging ahead with the Poseidon Undersea Resort, a $200 million development on a Fijian island. The centerpiece will be two dozen podlike underwater rooms, 12 along either side of a corridor as long as a football field. Each 550-square-foot luxury suite is to be encased in a clear acrylic shell, about 40 feet below the surface, a depth similar to Aquarius's. The resort has no firm opening date, but Jones claims the market for this five-star approach to undersea living is out there, even at a projected price of $15,000 for seven days and six nights.

Sylvia Earle, the leader of five female aquanauts in the Tektite II project, rehearses for an undersea mission in the Virgin Islands in July 1970.

A RESEARCH-ORIENTED project called SeaBase1 aims to tap the ecotourism market by giving recreational divers a chance to live as aquanauts and work alongside scientists, lending a hand with tasks like reef restoration. The hope is to place SeaBase1 on the east side of Ambergris Caye in Belize, where the local reef joins a contiguous, 500-mile-long chain that is second in length only to Australia's Great Barrier Reef. "The charge on us is to get her built, and once she's built we feel very confident that users will pay the operational costs," says Chris Cooper, vice president of SeaBase1 and the son of the project's founder,

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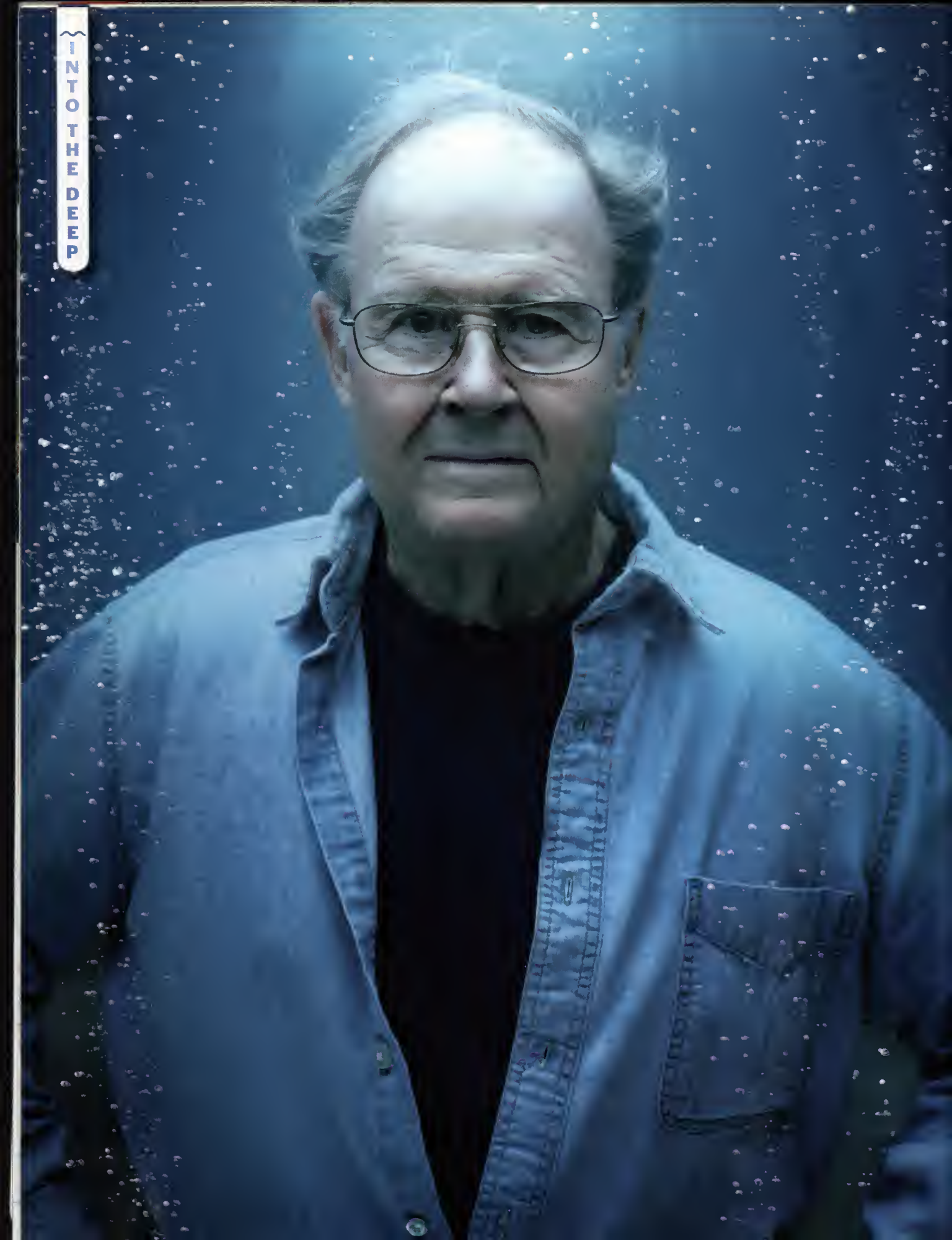


George Bass

The pioneering underwater archaeologist ignored academics who said he was wasting his time and professional divers who assumed he would not make it out of the water alive.

Much of human history is hidden beneath the waves: Some 3,000,000 shipwrecks may rest on the world's seabeds. But archaeologists had to rely on professional divers for scraps of information about these sites until the 1960s, when George Bass began to apply rigorous excavation techniques to underwater wrecks. Over the next half century, Bass led groundbreaking studies of Late Bronze Age (1600-1100 B.C.) shipwrecks off the coast of Turkey, along with sites from many other periods. Along the way, he transformed underwater archaeology from an amateur's pastime to a modern scientific discipline. Those achievements earned him a National Medal of Science in 2002. Now a professor emeritus at Texas A&M University, where he founded the Institute of Nautical Archaeology, Bass reflected on his storied career with DISCOVER senior editor (and passionate lover of archaeology) Eric A. Powell.

PHOTOGRAPHY BY RANDAL FORD

Q+A

Why go underwater to study the ancient past, when research is so much easier on land?

Underwater artifacts are protected against the most destructive agent of all, which is us. People drop plates and break them. They drop glass bottles and break them. They burn marble columns for lime. They melt down bronze statues for church roofs. Also, there are certain things that are simply not going to be found on land, like raw materials, because they don't remain raw for very long out of the water. The other reason to go underwater is that it's the place to find evidence of ship hulls, which were as important to ancient cultures as architecture, pottery, anything. There's always been a desire to transport goods or ideas as cheaply and in as great a quantity as possible. For much of human history, that meant building the best ship you could.

What can you learn from a ship hull?

Since at least the Bronze Age, seafaring has been key to cultural progress. Ships are in some cases the most technologically advanced equipment a culture would develop—their space shuttles. So to really understand the ancients, you have to be able to understand how they approached the sea, and the only way to do that is to excavate shipwrecks. And those ships only sank once, so they can give you incredibly precise dates.

Have you always been drawn to ships and the sea?

I grew up in Annapolis, Maryland, where my father taught English at the Naval Academy. My brother and I made a diving helmet out of a tin square that we cut out and put glass in

10 Undersea Tales

by Mary Beth Griggs

1 BRONZE AGE MERCHANT SHIP

CAPE GELIDONYA, TURKEY

Archaeologists long assumed the Greeks ran the economic show in the Mediterranean during the Late Bronze Age. Then, in the summer of 1960, George Bass excavated a ship dating to 1200 B.C. off the southern coast of Turkey. The vessel–the first completely excavated underwater–was carrying Near Eastern plaques (below), copper ingots, and other goods from the East to Greece, not vice versa. The site upended conventional wisdom about Bronze Age trade and marked the beginning of scientific underwater archaeology.

2 17TH-CENTURY SWEDISH WARSHIP

STOCKHOLM HARBOR

In 1628 the ornate Swedish warship *Vasa* (below) sank less than a mile into its maiden voyage. In 1961 archaeologists raised the ship from the seabed, making it the first major shipwreck to be recovered almost intact, and giving researchers a unique look at 17th-century naval warfare. In the early 2000s large deposits of sulfuric salts were found eating away at *Vasa*'s hull, prompting researchers to develop new conservation methods that could help save *Vasa* and other excavated ships.

as a faceplate. We would have died if we had ever tried it. I was also inspired by a retired Australian army officer named Ben Carlin, who made an amphibious jeep that went all around the world. He put it together two doors down from us. I used to help him after I came home from school—you know, tightening nuts. He thought he'd make his fortune from it. He wrote a couple of books about that jeep, but he never did make his fortune.

Were you also interested in archaeology from the beginning?

Not at first. When I was in high school, I fell in love with astronomy. Later I went to Johns Hopkins and started as an English major. But then I spent my sophomore year of college in England at the University of Exeter, and I got what they call "rusticated" for pulling a prank. Forty of us got suspended because we raided a local agricultural college. I had nowhere to go. My brother's roommate and some of his friends were going to Taormina, Sicily, for spring break and asked me to go with them. So here I was in Taormina, sitting out there in the evening and looking at a Roman theater with Mount Etna in the background, and I thought, you can make a living studying this stuff. Back at Johns Hopkins there was no archaeology department, but they made up a major for me with courses in the Near Eastern section and the classics section.

And then you had an amazing first experience as a field archaeologist.

I went to the American School of Classical Studies in Athens and then excavated at the site of Gordion in Turkey, the capital of King Midas's empire in the eighth century B.C. I found the first piece of gold, an earring, from the level of the site that dated to Midas's time.

You had to leave archaeology temporarily in 1957 to serve in the Army. Did that slow down your archaeological career?

Truth is, that was as important as any university degree I could have had. I was plunked down in a 30-man Army security unit in the middle of a rice paddy in Korea near the DMZ, the only American unit inside a Turkish brigade. It was a hardship outpost. The night I arrived the guys all got drunk and were rolling around in the rice paddies yelling obscenities at me. I was terrified; I didn't know what to do. Well, I grew up that night, I guess. Suddenly I was in charge of generators, trucks, the food, the operation. When I got back to the States, Rodney Young, an archaeologist at the University of Pennsylvania whom I'd worked with at Gordion, knew I'd had this formative experience. He had recently gotten a letter about a diver who'd found a Bronze Age shipwreck site off the coast of Cape Gelidonya in Turkey. Rodney asked If I'd like to go out and excavate this shipwreck.

Wait–did you even know how to dive at that point in your career?

I had to learn. So I joined the Depth Chargers at the Central YMCA in Philadelphia. My teacher was an ex-Navy diver who had lost an eardrum in a diving accident. At the end of the sixth lesson, we were still practicing snorkeling. I said to him one night, "Could I try a tank on once? I leave for Turkey tomorrow and the site is a hundred feet deep." And I found it very easy. I've never had any problems with diving.

So you started excavating at Cape Gelidonya in Turkey with only one diving lesson under your belt?

That's right—and it's in the worst current in the Mediterranean. Cape Gelidonya was the first ancient wreck excavated in its entirety on the seabed, the first excavated by a diving archaeologist. Before, archaeologists would sit on the deck like dogs waiting for a bone and accept artifacts brought up by divers for them. The divers always were saying archaeologists could never learn to dive. But we could! Cape Gelidonya showed it.

Cape Gelidonya dated to 1200 B.C., making it the earliest known shipwreck at the time.

FROM TOP: INA-KAROLINA KRISTENSSON/THE SWEDISH NATIONAL MARITIME MUSEUMS; OPPOSITE, FROM TOP: ROB CASEY; ANCIENT ART AND ARCHITECTURE COLLECTION LTD./THE BRIDGEMAN ART LIBRARY

> “Underwater archaeologists were sneered at for so long. No one took us seriously. They thought we were just a bunch of jock divers out there.”

What did those artifacts teach you about seafaring culture during that era?

At the start we all assumed it was a Mycenaean, or Late Bronze Age, wreck. All the English, German, and French sources indicated that Mycenaeans, the people of the Homeric epics, had a monopoly on maritime commerce back then. The reason was that Mycenaean pottery had been found all over Egypt, the Palestinian coast, and Cyprus. So when we found copper and tin ingots, which are used to make bronze, we assumed they were being shipped to Greece to be made into bronze.

Then I started studying pan balance weights that we excavated from the site. I saw certain weights repeating themselves—multiples of 9.32 grams. That's an Egyptian qedet. Or 7.20 grams, which was another standard unit in the Near East. And a lamp from the ship appeared to be Canaanite. I concluded that it was actually a Near Eastern ship, not Mycenaean after all. At that time all classical archaeologists thought that bronze had to come from Greece, that Greece was the center of civilization. But it's really a cultural bias.

You were criticized for identifying it as a Near Eastern wreck.

That excavation at Cape Gelidonya is the thing I'm proudest of in my career, and I didn't get a single favorable review from archaeologists for my publication. But we later confirmed that the ship was from Cyprus, which was then part of the Near Eastern world. Underwater archaeologists were sneered at for so long. No one took us seriously. We were just a bunch of skin divers.

“Skin diver”—why that insult?

Skin diving was a macho thing in those days. Archaeologists thought it was a bunch of jock divers out there. They didn't understand you can work more carefully underwater than you can on land. You can excavate one grain of sand at a time. You can't do that on land. I remember when an archaeologist, who shall remain nameless, called underwater archaeology “that silly stuff you people do, bringing up amphoras.” At that time we had the largest dated collection of seventh-century pottery in the world. He was publishing a book on late-Roman pottery going up to the seventh century A.D. and he was calling it silly stuff. I said, “What do you mean, ‘silly’?” He said, “Well, you can't do careful work underwater.” And I said, “Yeah, you can. We map things very accurately.” He couldn't

3 VIKING SHIPS

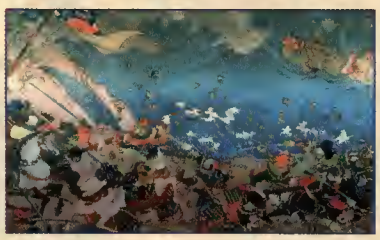
ROSKILDE, DENMARK

Most shipwrecks are the victims of unforeseen catastrophe, but five Viking-era ships excavated in 1962 near the Danish town of Roskilde, outside Copenhagen, were sunk on purpose. The ships (detail, above) formed part of an underwater rock barrier that was constructed in the 11th century to protect Roskilde from sea raids. Centuries underwater had made matchsticks of the ships' hulls, but researchers managed to piece them together from more than 100,000 splintered bits of wood. The vessels gave archaeologists an unprecedented look at Viking shipbuilding techniques.

4 KAMIKAZE FLEET

TAKASHIMA ISLAND, JAPAN

Legend has it that when Kublai Khan, the Mongol emperor of China, invaded Japan in 1281, his fleet was destroyed by a typhoon the Japanese dubbed a *kamikaze*, or “divine wind.” Celebrated in art (such as the 19th-century engraving below), the tale persisted, unproven, until the 1980s, when archaeologists diving off the small island of Takashima found copper coins, metal helmets, and arrowheads dating to the 13th century. Last year's discovery of the substantial remains of a ship confirmed that the khan's fleet has indeed been found.



5 UNION WARSHIP
OUTER BANKS, NORTH CAROLINA

On December 31, 1862, the USS *Monitor* sank in rough waters off the coast of North Carolina, carrying 16 Union sailors to their deaths. The wreckage of the ironclad warship was discovered by sonar in 1973. Over the next 20 years, archaeologists removed 210 tons of relics from the seafloor, including the ship's iconic gun turret (seen in an 1862 photograph above) and more intimate objects like buttons and silverware used by the sailors on board. While conserving the ship's remains, researchers were able to study the inside of *Monitor*'s 20-ton, 400-horsepower engine, one of the most advanced of its time.

6 SUNKEN CARIBBEAN PORT
PORT ROYAL, JAMAICA

Shipwrecks are not the only important archaeological sites preserved underwater. Nestled along the southern Jamaican coast are the remains of Port Royal, a colonial city (and pirate haven) that partially sank into the sea after a devastating earthquake in 1692; some of the town's neighborhoods dropped 15 feet in an instant. Excavated from 1981 to 1990, Port Royal offers a glimpse into both the panicked moments after the earthquake and the everyday lives of Port Royal's 17th-century residents, commoners who rarely show up in historical documents. Archaeologists have made discoveries both poignant–a pocket watch from the site forever set to 11:40 a.m., around the time of day the earthquake hit–and prosaic, such as hair clippings, perhaps from a pirate's recent haircut, and intact glass liquor bottles (right).

> "Eventually I thought, I've had a decade of doing this. The odds are that one day someone will die. Why don't I just get out of it now while I'm ahead?"

accept the fact that a diver is not just some clumsy guy with lead shoes.

After Cape Gelidonya you went on to excavate other sites, including a seventh-century Byzantine shipwreck at Yassi Ada, an island off the western coast of Turkey. How did you find these sites?

Almost all the wrecks were shown to us by Turkish sponge divers. Based on the number of sponge boats, the number of divers, how long they go down, and how deep they go—all that stuff—we calculated once that if we interviewed every sponge diver about what they saw on the bottom, we'd learn as much as if one of us nautical archaeologists swam for a year. Some would say, yeah, but they are not doing scientific searches. Baloney. They were doing better searches than we ever did. Their livelihoods depended on it.

Despite your success, in 1969 you abandoned underwater archaeology. Why?

At Yassi Ada, one of our most skilled, experienced divers, Eric Ryan, was very near death when we pulled him from the water with an embolism. And then we had a sponge diver also brought to us with the bends, or decompression sickness, which is caused by nitrogen bubbles forming in your blood if you come up too quickly. It was horrible. He was calling out to his wife and Allah. He died during treatment in our decompression chamber. Eventually I thought, I've had a decade now of doing this. The odds are that one day, maybe a coed will die and I'll have to lift her dead body out of the water. Why don't I just get out of it now while I'm ahead? I've tempted fate too often.

You switched to work on land at a site in southern Italy. Why there?

It was a Neolithic [6000-2800 B.C.] site. We were trying to determine when domestic animals were introduced into that part of Italy. We thought we might be able to study the bones and pottery to find that out. It didn't work, and I remember thinking that out there somewhere in the Adriatic was probably a shipwreck that would answer this question so much better. Also, I just missed the smell of the sea and the seagulls and the rope and the smell of tar and all the things that surround boats.

So you hatched a plan to get back to your true love, underwater archaeology.

In 1972 my colleague Fred van Doorninck at U.C. Davis came and stayed at our house in Philadelphia

FROM TOP: MATHEW B. BRADY/ART RESOURCE, PORT ROYAL PROJECT/TEXAS A&M UNIVERSITY. OPPOSITE, FROM TOP: COLLECTION OF THE MONTEREY HISTORY & ART ASSOCIATION; WENDY WELSH/NC DEPARTMENT OF CULTURAL RESOURCES

to work on this final publication about the Byzantine wreck at Yassi Ada. And we started talking about this little dream: What if we had an institute devoted to underwater archeology? We were naive. We thought we could get a compound out on a peninsula on the Turkish coast and grow our own vegetables and buy ourselves a trawler.

How did you finally take the plunge and turn that dream into something real?

One day I got a call from a woman who said, "There's this big piece of wood that's washed up on the beach here in New Jersey." She was wondering if it might be a Viking ship, and would I come down and look at it? My friend Dick Steffy, an electrician who built accurate ship models, and I went out and quickly saw it was modern, built in Maine around 1890. Then while we were driving home in separate cars I noticed Dick waving out of the window to stop. We pulled over to the side of the highway, he walked back toward me, and he said, "George, I've decided I'm going to make a career as an ancient shipwreck reconstructor." I said, "Dick, there is no such thing. You've got a wife and children. You'll starve to death." He said, "If you don't try something, you'll just die and never know whether it would've worked." I listened to him, and shortly thereafter I decided to leave Penn to found an underwater archaeology institute.

Eventually you found a home for the institute at Texas A & M and set up a series of intensive underwater surveys and excavations around the United States, the Caribbean, and off the coast of Turkey. Which site do you view as most important?

No question, it is the Bronze Age wreck we excavated at Uluburun, Turkey, not far from Cape Gelidonya. A sponge diver reported seeing "strange metal biscuits with ears," which were copper ingots, at the site. With my colleague Cemal Pulak taking the lead, we found the shipwreck, excavated it, and discovered it had 20 tons of raw materials, things that had never been seen before: intact tin ingots, almost 200 glass ingots, and ebony logs. We had half a ton of resin called terebinth, which was probably burned as incense. These are things you just never find on land. We had 10 tons of copper and 1 ton of tin, which is exactly the right proportion for 11 tons of bronze. Like the Cape Gelidonya wreck, the ship was clearly coming from the East, maybe the Palestinian coast, and carrying goods to Greece. It was an unprecedented window onto the Bronze Age economy.

How did that change our thinking about life in the Bronze Age?

You name it—it contributed to so many fields: the study of weapons, the history of glass, the history of metallurgy, the history of ship construction, just endless.

Looking ahead, what kind of technology will nautical archaeologists need to keep the field advancing?

The one I'm waiting for is a one-atmosphere flexible diving suit. That's a diving suit that would be flexible but could still withstand enormous pressure. It would allow divers to go down and excavate for hours at a time without worrying about decompression. That would revolutionize the field. Right now we can only work twice a day for 20 minutes at a time because of complications due to the pressure at great depths.

What are the greatest discoveries left to be made in nautical archaeology?

There's a whole unknown early nautical history. Crete was suddenly colonized with domestic animals in 6000 B.C., so there must have been rafts or some kind of seafaring craft at that time. Same with Australia—but it was settled 40,000 years ago or more. There's no reason why remains of the craft they used couldn't survive, if they were protected by sand and sealed from decomposition. They just haven't been found yet. It would also be interesting to know what kind of craft the Mesopotamians used. And I

7 AMERICAN ZEPPELIN

BIG SUR, CALIFORNIA

Imagine the *Titanic* floating overhead: That's what it would have been like to see the USS *Macon* fly by. Nearly 800 feet long, the airship was completed in 1933 as part of an effort to equip the U.S. Navy with airborne military bases. With an onboard hangar, *Macon* (below) was capable of launching five small fixed-wing planes in midair, but it never saw action and went down off California's Big Sur coast during a storm in 1935. Rediscovered in 1980 when a fisherman caught a piece of the airship's debris in his net, the wreck was recently surveyed and mapped using sonar and remotely operated robots. Government archaeologists continue to explore the unique site, which lies in 1,500 feet of water.

8 A PIRATE'S FLAGSHIP

NORTH CAROLINA COAST

In the early 18th century, Blackbeard was the most feared of the pirates who preyed on vessels traveling to and from the American colonies. His specter returned in 1996, when archaeologists searching off the North Carolina coast discovered Blackbeard's flagship, the *Queen Anne's Revenge*, which ran aground in 1718 as the pirates fled English warships. A team has excavated at the site ever since, recovering cannons, a copper disk depicting Queen Anne herself (below), and personal effects such as pipes. What the crew left behind and what they took as they evacuated tell researchers what pirates of that period valued most–information that ships' logs did not record.

9 PHOENICIAN TRADER
BAJO DE LA CAMPANA, SPAIN

Along Spain's southeastern coast, a treacherous rock formation called Bajo de la Campana has claimed many ships through the years. They included a 7th-century B.C. Phoenician trading vessel of a type depicted in contemporary wall reliefs (below). The recent excavation of the ship opened a window onto the maritime economy of the Phoenicians, a Near Eastern people who built a trading empire throughout the Mediterranean from 1500 to 600 B.C. As it sank, the ship left a trail of artifacts on the seafloor, including tin ingots, elephant tusks, and vials of perfumed oils, illustrating just how active the Phoenician trading system was. The vessel was most likely bound for a Phoenician colony just north of the wreck site.

10 HMS *INVESTIGATOR*
BANKS ISLAND, CANADA

The British navy sent *Investigator* to the Arctic in 1850 to search for a doomed expedition led by explorer John Franklin. But *Investigator* was also unlucky. Its crew abandoned the ship after it was trapped in ice 500 miles north of the Arctic Circle. In 2010 archaeologists used sonar to find the ship sitting upright in 36 feet of water. Dives at the wreck gave researchers a new look at how the British outfitted vessels for polar navigation. Modifications made to strengthen the bow (below) and hull against ice allowed the wreck to survive virtually unscathed for 160 years.

> “There's a whole unknown early nautical history. Australia was settled 40,000 years ago. There's no reason why remains of the craft they used couldn't survive.”

would love to do a survey of the Red Sea and find a pharaonic ship.

What about sites we already know about? Is there more to be discovered there?

Of course. We recently re-excavated Cape Gelidonya with better equipment, better metal detectors, and found the site is larger than we thought. We found that pottery extended to the base of a rock that rises to just below the surface. The diver and photojournalist Peter Throckmorton, who first identified the site, thought maybe the ship had hit that rock. Then 50 years later we found a trail of artifacts from that rock to the rest of the site, confirming his hunch.

That's an incredible leap through time, to a specific moment 3,200 years ago. When you're at a site, do you imagine what it was like to be aboard the sinking ship?

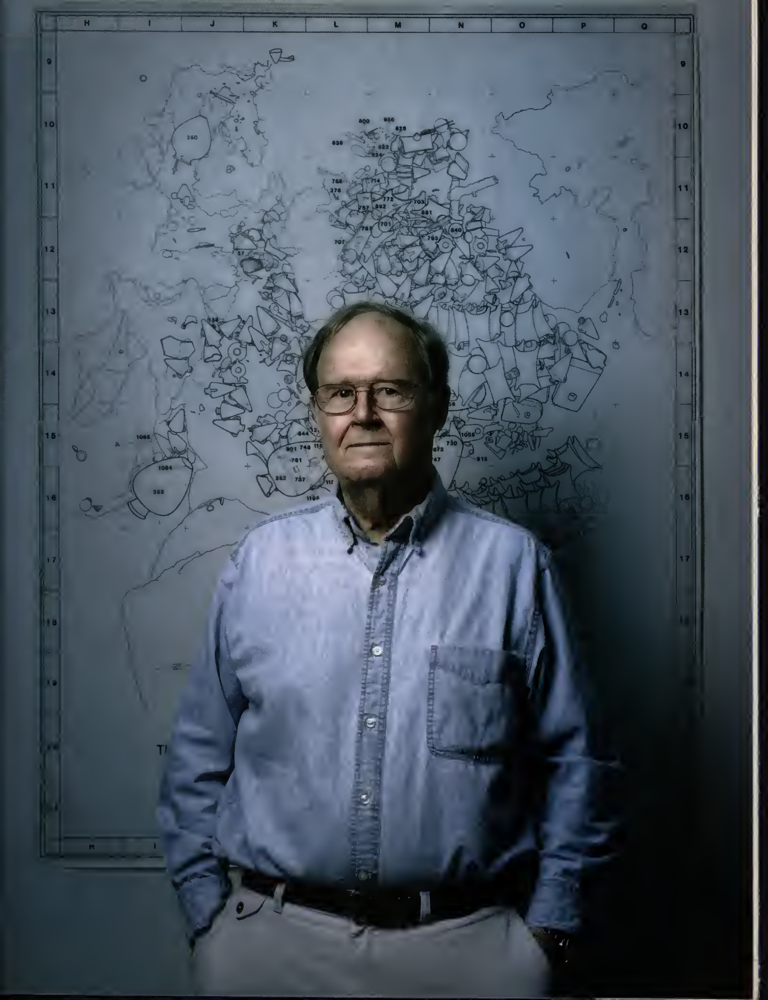
Back when I was running excavations, I was more worried about keeping my crew alive. But after I retired I was looking through some family history compiled by my grandfather. I found a note: "William Jessup Armstrong, grandfather, lost in the sinking of the *Atlantic*." I'd never heard of that, so I went down to the library and learned that the *Atlantic* sailed from Connecticut just before Thanksgiving in 1846 with some 80 people aboard. Then something blew up on the ship, and it was drifting in a terrible storm not far from shore. Forty people died, and on the list, there's his name: "Lost—the Reverend Doctor Armstrong." So I visited where the *Atlantic* went down and discovered that people have collected spoons and things from the site. That led me to think about all the stuff I've collected from shipwrecks over the years.

How did that change the way that you conceptualize the past?

When I excavated a classical Greek shipwreck at a site called Tektas Burnu, my students asked me, "Do you think anyone made it ashore?" And I said, "Of course, it sank just a few feet from shore." But you know what? The shore's got jagged rocks, and with a storm, they would've had waves crashing over them. I hadn't thought about it until this. The *Atlantic* went aground on a beach, and yet still half the passengers died. It just brought it home: Every one of these shipwrecks we excavate is possibly a site of terrible human tragedy.

George Bass stands in front of a map of the Uluburun shipwreck, a Bronze Age site his team excavated that rewrote nautical history.

FROM TOP: THE TRUSTEES OF THE BRITISH MUSEUM; PARKS CANADA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the POWER of MILK

Breast-feeding boosts an infant's immune system and promotes a healthy gut. Scientists are finally isolating the compounds responsible. The result could be a health breakthrough for all ages.

PERLA LEWIS-TRUONG'S DUE DATE WAS MARCH 1. BUT THE DAY AFTER Thanksgiving, she was admitted to the hospital with severe preeclampsia, a disorder marked by a rapid rise in blood pressure that puts a mother's health and pregnancy at risk. A week later doctors had to deliver her daughter by cesarean section, 13 weeks early. Baby Celia weighed only a pound and a half. After two months, she is four pounds and still nearly translucent but healthy, lying in a small heated pod in the Children's Hospital of the University of California, Davis, in Sacramento. Celia was lucky to be born here, at a teaching hospital with an advanced neonatal intensive care unit. Premature babies face many potential problems, including necrotizing enterocolitis, in which intestinal walls deteriorate and bacteria invade. A quarter of infants with the disease die, and survivors may suffer neurological problems for years.

Mark Underwood, a neonatologist at U.C. Davis, is constantly seeking better treatments for his delicate patients. Contrary to traditional practice, his focus is not on drugs but on diet. Underwood believes that many cases of necrotizing enterocolitis could be prevented by giving preemies a special daily cocktail of probiotics (healthy bacteria) and prebiotics (the food those bacteria eat), all inspired by what might be considered the ultimate superfood: human milk.

"Milk is powerful as a preventer of disease and an enhancer of performance," says Bruce German, a food chemist at U.C. Davis. "By understanding how it does what it does, we can bring the principles, the mechanisms of action, and the benefits to everyone." Human milk's most important role could be preventing infant disease and

by FLORENCE WILLIAMS

PAOLA DE GRENET/MILLENNIUM IMAGES

boosting immunity by cultivating a balance of microbes in the gut and the rest of the body, a kind of internal ecosystem called the microbiome. In fact, many researchers now believe that mammalian lactation originally evolved as a protective, not a nutritional, adaptation.

Consider baby Celia's situation at Davis. It is an impressive hospital, but even the best neonatal intensive care unit presents a challenging environment for a preemie. Fetuses are bacterially naive, with little exposure to pathogens or other microbes before birth. Then they get exposed in a very specific way: first through the birth canal, a wellspring of bacteria, and then through near-constant snuggling with their moms—ideally accompanied by immediate breast-feeding. Within days, microbes both good and bad start to colonize the baby and help educate the immune system. But Celia, born through a C-section and then placed in an isolette, acquired most of her bacteria not from her mother but from a hospital. Too young to breast-feed, she received nourishment, including liquid vitamins and a few drops of her mother's milk, through a catheter in her umbilical cord.

"We think that makes them sick," says Underwood, a soft-spoken man in glasses and a blue polo shirt. For preemies, infections come fast and furious, but those who receive breast milk are half as likely to suffer from necrotizing enterocolitis as their formula-fed peers. Such statistics are driving Underwood and his colleagues to peer deeper into human milk. And their findings are poised to improve health not just for babies, but for all of us.

Once we isolate the active ingredients of human milk, they might help fight everything from cancer to HIV.

FOR A SUBSTANCE SO IMPORTANT TO THE success of our species, human milk has, until recently, been largely neglected by researchers. For one thing, most infants in the developed world can now survive without it. Doctors and scientists long assumed most of its value was nutritional, in which case it could be replaced by commercial infant formula, which is now a $3.5 billion-a-year business in the United States alone.

Far more money has gone into improving efficiencies in the dairy industry or studying the cholesterol-reducing effects of red wine than into understanding human breast milk. "People should not underestimate how important the money is," says food researcher Bruce German from his office in the new, light-dappled Robert Mondavi Institute for Wine and Food Science on the Davis campus.

German had his lightbulb moment in 1994, when he decided that food scientists were "overblowing the red wine thing." He asked himself, what is the one food that's clearly meant to help humans? German, a ruddy man in a white sweater vest that looks knit by a relative, answers his own question effusively: "Milk!"

German took a sabbatical in Switzerland to work at food giant Nestlé, one of the world's leading sellers of infant formula. Where better to learn about human milk, he reasoned, than at a company so keen to mimic it? Nestlé researchers suspected that milk could "grab onto pathogens," flushing them out of the baby, and even act as an anti-inflammatory, calming hypervigilant, immature immune cells. But like other researchers, they didn't know the mechanism involved. If only the means of action could be decoded, and the healthy components isolated, identified, and produced in quantity, German thought, then they could be repurposed to treat everything from diarrheal diseases to cancer to HIV.

One class of substances in particular intrigued German: oligosaccharides. These sugar molecules, among the most common solid components of milk, are not digestible. Since we cannot metabolize them, he wondered, why are they there in such abundance? He had a hunch that the answer might be related to the human microbiome. If the molecules are not feeding us, he reasoned, maybe they are feeding the microbes that boost our health. On his return to Davis, German began collaborating with molecular biologists and chemists to isolate the oligosaccharides and test them against various bacteria.

To date, researchers have discovered more than 150 different human-milk oligosaccharides and believe there may be some 200 altogether. Built in combinations of 3 to 20 monosaccharides (simple sugars), these compounds are hard to fragment and analyze. German's colleague Carlito Lebrilla decided to attempt the job with the university's new nanoflow liquid chromatography time-of-flight machine, which identifies molecules by measuring the time it takes them to ping around a tube that looks like a stovepipe. In order to separate the 200-some compounds in breast milk so they could be analyzed individually, Lebrilla worked with a biotech company to develop a microchip that acts like a filter for the machine, allowing different compounds through at different speeds.

Another helpful technology was a superconducting magnet cyclotron—a million-dollar drum-shaped device that sends molecules racing around in circles. Researchers can blast the compounds apart with lasers and measure the mass of the molecular fragments that spew out, like smashing a geode to see what minerals are inside. Through painstaking work, German and his colleagues eventually identified dozens of new sugars that could be keys to human health and disease.

At another lab in Davis's food-science complex, the effort is on to see just what these sugars actually do. At the heart of the effort is microbiologist David Mills, who spent years growing finicky bacteria in test tubes laced with oligosaccharides in oxygen-deprived chambers that mimic conditions in the human gut. It is not a project for the squeamish: To recreate the biology as exactly as he can, Mills works with fecal bacteria collected from infant stool samples. In this way he discovered that *Bifidobacterium infantis*, one of the dominant bacteria present in the poop of healthy breast-fed babies, is particularly good at eating large oligosaccharides capped at the end with a particular kind of sugar unit. These molecules, called large fucosylated oligosaccharides, are plentiful in breast milk

despite the fact that humans cannot digest them at all. But *B. infantis* can. The microbe efficiently eats these sugars before other bacteria get to them, starving out bad bugs and aiding the infant that serves as its host.

At the Davis neonatal intensive care unit, concentrated breast milk rich with oligosaccharides is now being tested in babies unable to grow enough *B. infantis* on their own. The hope is that seeding their guts with regular doses of the bacterium and the sugar it eats will compensate for that lack. The *B. infantis* supplement is brewed in a food-grade facility and turned into a soluble powder. Underwood, German, and their colleagues believe it will have major potential, not just for preemies but for babies and small children in the developing world who suffer high rates of other gut infections leading to diarrheal disease.

Assuming this and several other related human trials currently under way are a success, the next step will be making enough of these crucial breast-milk sugars and doing it cheaply. One idea for ramping up production is through dairy cows, which naturally produce many of the same oligosaccharides as humans do, though in tiny quantities. Fortunately, California's dairy industry produces more than 3,000 tons of cheese a day, and a corresponding amount of liquid whey that is extracted from it. Supported by funding from the Gates Foundation, U.C. Davis is working to find an efficient way to partition out and concentrate the human-active compounds.

Other breast-milk oligosaccharides are also showing promise. At the University of California, San Diego, a sugar called disialyllacto-N-tetraose reduced the mortality rate from necrotizing enterocolitis in rats from 25 percent to only 5 percent. Nutritional scientist Lars Bode believes the compound may act by encouraging the growth of beneficial bacteria or by reducing inflammation of the gut.

Bode's lab has shown that the same family of compounds ably attach to a protozoan parasite and potentially lethal pathogen, *Entamoeba histolytica*. Bode believes these sugars, because they are indigestible, journey intact to the colon, where their structure mimics molecules on the surface of gut epithelial cells. When the parasite tries to hook onto the intestinal wall, it latches onto the milk decoy instead. The milk molecules then most likely flush the parasite out. Bode's finding could have big implications for both child and adult health, because *E. histolytica* is the world's third-leading cause of death by parasites. These particular oligosaccharides would be expensive to synthesize in a lab, but simpler sugars derived from cow's milk also appear to work well against *E. histolytica*.

Bode points to human-milk oligosaccharides performing other heroic medical feats. They inhibit *Streptococcus pneumoniae*, the bacterium frequently responsible for respiratory and ear infections, which may explain why breast-fed infants get fewer respiratory illnesses than formula-fed ones. And at Boston College, biochemist David Newburg and his colleagues have found that another oligosaccharide called 2'-fucosyllactose is effective at warding off *Campylobacter*, cholera, and enteropathogenic *E. coli*—a frequent cause of diarrhea—in animal models. He believes it has the same impact in humans.

COCKTAILS OF MILK-DERIVED COMPOUNDS could soon start moving from the lab to medical use. Newburg has cofounded Glycosyn, Inc. to test his oligosaccharide in humans within two years. The company makes 2'-fucosyllactose from yeast and bacteria and is working toward marketing a nutritional supplement for children in the developing world, where diarrheal diseases kill more than a million of them a year. Especially at risk are newborns and weaning toddlers, who lose the protection of mother's milk at the same time they are exposed to a wider variety of food pathogens. Newburg and his collaborators are also studying a human-milk fat that seems to inhibit HIV from infecting human cells, and yet another milk component that prevents HIV from disabling the host's immune cells.

The big infant formula producers are closely watching these promising breast milk studies. Abbott, Mead Johnson, the British company Aptamil, and the German company HiPP have begun offering formula with a prebiotic called GOS, for galacto-oligosaccharide, derived from cow's-milk lactose. At least two companies have started supplementing formula with probiotics. HiPP uses a strain of human-milk *Lactobacillus* to help ward off infections. And Nestlé's Gerber has introduced an infant formula with bifidobacteria to support infants' immune systems. "There's a whole lot happening," Newburg says. "The formula companies are all partnering up to get a supply, get prepared, and do big human testing."

New milk-inspired therapies may soon find their way into the intensive care unit, too. Back at U.C. Davis, Mark Underwood is working on his next project, developing lipids from human milk to bathe and protect preemie skin. Bruce German responds with characteristic enthusiasm. "It's better than Vaseline!"

Florence Williams is the author of *Breasts: A Natural and Unnatural History*, published this May by W. W. Norton & Company.

Breast Milk Therapies for Adults

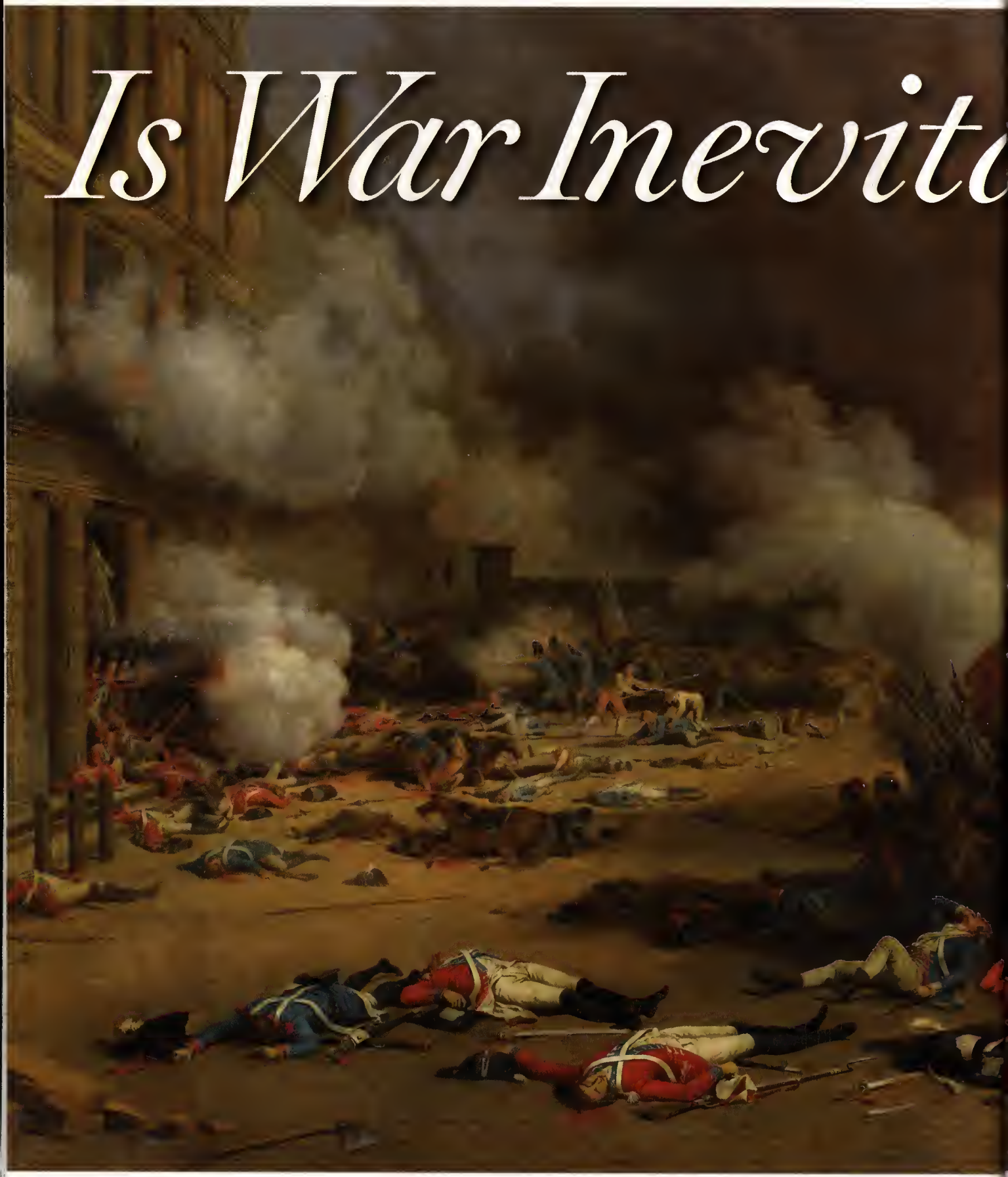
The first round of milk-derived drugs are aimed at infants and children. But such compounds could soon also be aiding grown-ups–especially those whose internal population of microbes, or microbiomes, have been damaged due to illness, age, or antibiotics and other drugs.

CD14, a cell surface protein abundant in human milk, is present when the immune system learns to fight pathogens in the intestines. Nestlé researchers think the protein could turn out to help adult patients suffering from the immune responses that cause Crohn's disease.

LACTOFERRIN, a human-milk protein that binds iron, helps the body fight shigella, salmonella, *E. coli*, and other microbes that feed on iron. A supplement called Lactoferrin Gold 1.8, marketed by Nikken in Japan, is made from the milk of transgenic cows manipulated to have a human lactoferrin gene. The current process for producing lactoferrin is so inefficient that it requires nearly a gallon of cow's milk to create just one capsule of the stuff. Yet the treatment may be worth it for the most vulnerable. Already shown to work in pigs, whose immune systems are much like ours, lactoferrin could provide a boost for those with compromised immune systems such as infants, the elderly, and the chronically ill.

LYSOZYME, an enzyme found in low levels in human milk, has been shown to kill *E. coli* in mice and pigs; it could soon find medical applications. To boost production of the enzyme in animals, U.C. Davis scientists have transferred the human gene for the enzyme into dairy goats. Although regulations prevent the transgenic milk product from being sold, the researchers are working with the Brazilian government to test it in the northeastern part of the country, where childhood diarrhea is common and some areas have infant mortality rates up to 10 percent. F. W.

Is War Inevito



...ble?

Human evolution has been defined by conflict, says one of the world's leading biologists. War is embedded in our very nature.

BY E. O. WILSON

Jacques Bertaux's 1795 painting depicts the brutality of the French Revolution.

G. BLOT/J. SCHORMANS/RÉUNION DES MUSÉES NATIONAUX/ART RESOURCE, NY

"HISTORY IS A BATH OF BLOOD," wrote William James, whose 1906 antiwar essay is arguably the best ever written on the subject. "Modern man inherits all the innate pugnacity and all the love of glory of his ancestors. Showing war's irrationality and horror is of no effect on him. The horrors make the fascination. War is the strong life; it is life in extremis; war taxes are the only ones men never hesitate to pay, as the budgets of all nations show us."

Our bloody nature, it can now be argued in the context of modern biology, is ingrained because group-versus-group competition was a principal driving force that made us what we are. In prehistory, group selection (that is, the competition between tribes instead of between individuals) lifted the hominids that became territorial carnivores to heights of solidarity, to genius, to enterprise—and to fear. Each tribe knew with justification that if it was not armed and ready, its very existence was imperiled. Throughout history, the escalation of a large part of technology has had combat as its central purpose. Today the calendars of

nations are punctuated by holidays to celebrate wars won and to perform memorial services for those who died waging them. Public support is best fired up by appeal to the emotions of deadly combat, over which the amygdala—a center for primary emotion in the brain—is grandmaster. We find ourselves in the "battle" to stem an oil spill, the "fight" to tame inflation, the "war" against cancer. Wherever there is an enemy, animate or inanimate, there must be a victory. You must prevail at the front, no matter how high the cost at home.

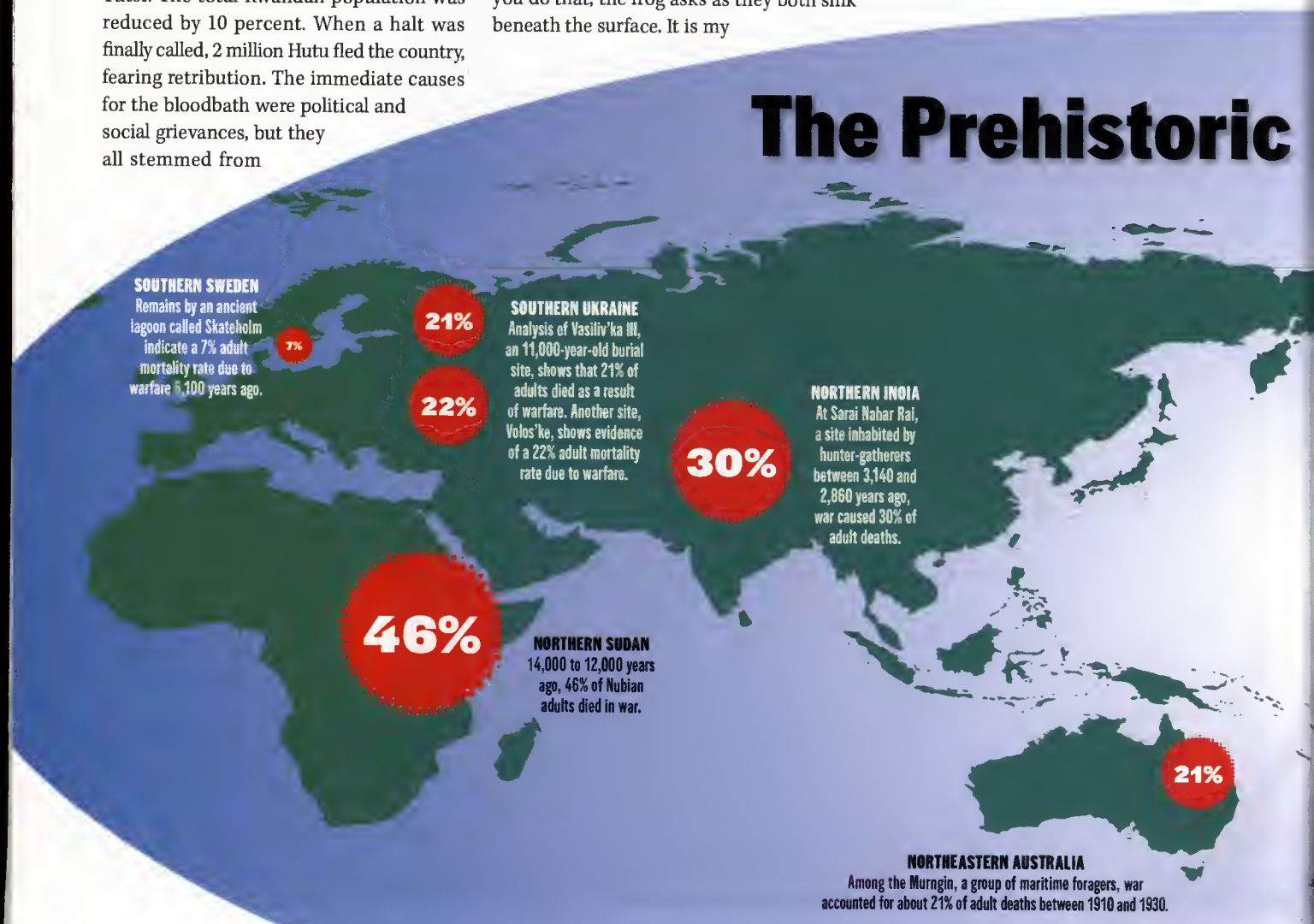
Any excuse for a real war will do, so long as it is seen as necessary to protect the tribe. The remembrance of past horrors has no effect. From April to June in 1994, killers from the Hutu majority in Rwanda set out to exterminate the Tutsi minority, which at that time ruled the country. In a hundred days of unrestrained slaughter by knife and gun, 800,000 people died, mostly Tutsi. The total Rwandan population was reduced by 10 percent. When a halt was finally called, 2 million Hutu fled the country, fearing retribution. The immediate causes for the bloodbath were political and social grievances, but they all stemmed from one root cause: Rwanda was the most overcrowded country in Africa. For a relentlessly growing population, the per capita arable land was shrinking toward its limit. The deadly argument was over which tribe would own and control the whole of it.

UNIVERSAL CONFLICT

Once a group has been split off from other groups and sufficiently dehumanized, any brutality can be justified, at any level, and at any size of the victimized group up to and including race and nation. And so it has ever been. A familiar fable is told to symbolize this pitiless dark angel of human nature. A scorpion asks a frog to ferry it across a stream. The frog at first refuses, saying that it fears the scorpion will sting it. The scorpion assures the frog it will do no such thing. After all, it says, we will both perish if I sting you. The frog consents, and halfway across the stream the scorpion stings it. Why did you do that, the frog asks as they both sink beneath the surface. It is my nature, the scorpion explains.

War, often accompanied by genocide, is not a cultural artifact of just a few societies. Nor has it been an aberration of history, a result of the growing pains of our species' maturation. Wars and genocide have been universal and eternal, respecting no particular time or culture. Archaeological sites are strewn with the evidence of mass conflicts and burials of massacred people. Tools from the earliest Neolithic period, about 10,000 years ago, include instruments clearly designed for fighting. One might think that the influence of pacific Eastern religions, especially Buddhism, has been consistent in opposing violence. Such is not the case. Whenever Buddhism dominated and became the official ideology, war was tolerated and even pressed as part of faith-based state policy. The rationale is simple, and has its mirror image in Christianity: Peace, nonviolence, and brotherly love are core values,

The Prehistoric



but a threat to Buddhist law and civilization is an evil that must be defeated.

Since the end of World War II, violent conflict between states has declined drastically, owing in part to the nuclear standoff of the major powers (two scorpions in a bottle writ large). But civil wars, insurgencies, and state-sponsored terrorism continue unabated. Overall, big wars have been replaced around the world by small wars of the kind and magnitude more typical of hunter-gatherer and primitively agricultural societies. Civilized societies have tried to eliminate torture, execution, and the murder of civilians, but those fighting little wars do not comply.

Archaeologists have determined that after populations of *Homo sapiens* began to spread out of Africa approximately 60,000 years ago, the first wave reached as far as New Guinea and Australia. The descendants of the pioneers remained as hunter-gatherers or at most primitive agriculturalists, until reached by Europeans. Living populations of similar early provenance and archaic cultures are the aboriginals of Little Andaman Island off the east coast of India, the Mbuti Pygmies of Central Africa, and the !Kung Bushmen of southern Africa. All today, or at least within historical memory, have exhibited aggressive territorial behavior.

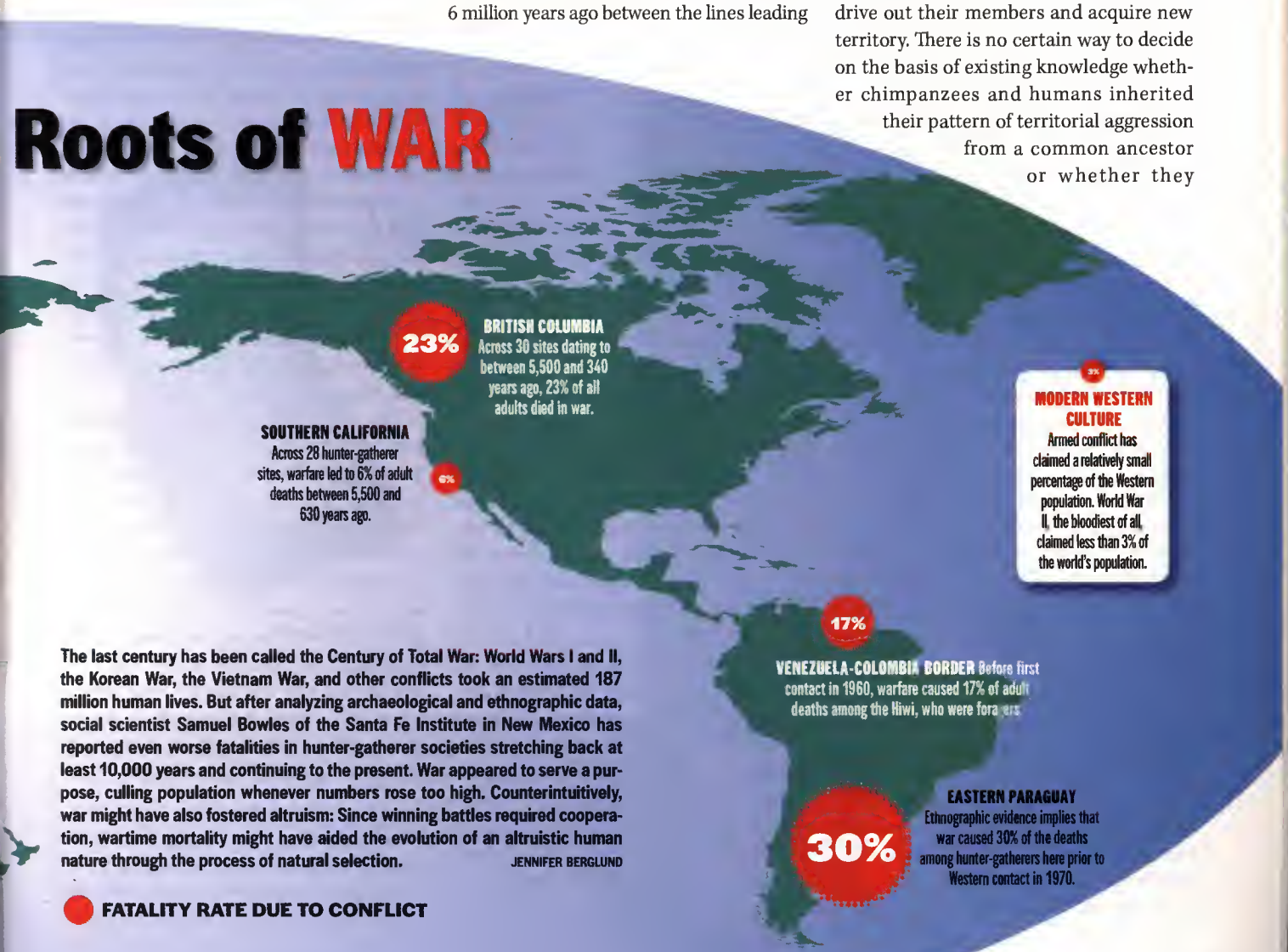
LETHAL LEGACY

Tribal aggressiveness goes back well beyond Neolithic times, but no one as yet can say exactly how far. It could have begun at the time of *Homo habilis*, the earliest known species of the genus *Homo*, which arose between 3 million and 2 million years ago in Africa. Along with a larger brain, those first members of our genus developed a heavy dependence on scavenging or hunting for meat. And there is a good chance that it could be a much older heritage, dating beyond the split 6 million years ago between the lines leading to modern chimpanzees and to humans.

A series of researchers, starting with Jane Goodall, have documented the murders within chimpanzee groups and lethal raids conducted between groups. It turns out that chimpanzees and human hunter-gatherers and primitive farmers have about the same rates of death due to violent attacks within and between groups. But nonlethal violence is far higher in the chimps, occurring between a hundred and possibly a thousand times more often than in humans.

The patterns of collective violence in which young chimp males engage are remarkably similar to those of young human males. Aside from constantly vying for status, both for themselves and for their gangs, they tend to avoid open mass confrontations with rival troops, instead relying on surprise attacks. The purpose of raids made by the male gangs on neighboring communities is evidently to kill or drive out their members and acquire new territory. There is no certain way to decide on the basis of existing knowledge whether chimpanzees and humans inherited their pattern of territorial aggression from a common ancestor or whether they

Roots of WAR



The last century has been called the Century of Total War: World Wars I and II, the Korean War, the Vietnam War, and other conflicts took an estimated 187 million human lives. But after analyzing archaeological and ethnographic data, social scientist Samuel Bowles of the Santa Fe Institute in New Mexico has reported even worse fatalities in hunter-gatherer societies stretching back at least 10,000 years and continuing to the present. War appeared to serve a purpose, culling population whenever numbers rose too high. Counterintuitively, war might have also fostered altruism: Since winning battles required cooperation, wartime mortality might have aided the evolution of an altruistic human nature through the process of natural selection. JENNIFER BERGLUND

● **FATALITY RATE DUE TO CONFLICT**

evolved it independently in response to parallel pressures of natural selection and opportunities encountered in the African homeland. From the remarkable similarity in behavioral detail between the two species, however, and if we use the fewest assumptions required to explain it, a common ancestry seems the more likely choice.

The principles of population ecology allow us to explore more deeply the roots of mankind's tribal instinct. Population growth is exponential. When each individual in a population is replaced in every succeeding generation by more than one—even by a very slight fraction more, say 1.01—the population grows faster and faster, in the manner of a savings account or debt. A population of chimpanzees or humans is always prone to grow exponentially when resources are abundant, but after a few generations even in the best of times it is forced to slow down. Something begins to intervene, and in time the population reaches its peak, then remains steady, or else oscillates up and down. Occasionally it crashes, and the species becomes locally extinct.

What is the "something"? It can be anything in nature that moves up or down in effectiveness with the size of the population. Wolves, for example, are the limiting factor for the population of elk and moose they kill and eat. As the wolves multiply, the populations of elk and moose stop growing or decline. In parallel manner, the quantity of elk and moose are the limiting factor for the wolves: When the predator population runs low on food, in this case elk and moose, its population falls. In other instances, the same relation holds for disease organisms and the hosts they infect. As the host population increases, and the populations grow larger and denser, the parasite population increases with it. In history diseases have often swept through the land until the host populations decline enough or a sufficient percentage of its members acquire immunity.

There is another principle at work: Limiting factors work in hierarchies. Suppose that the primary limiting factor is removed for elk by humans' killing the wolves. As a result the elk and moose grow more numerous, until the next factor kicks in. The factor may be that herbivores overgraze their range and run short of food. Another limiting factor is emigration, where individuals have a better chance to survive if they leave and go someplace else. Emigration due to population pressure is a highly developed instinct in lemmings, plague locusts, monarch butterflies, and wolves. If such populations are prevented from emigrating, the populations might again increase in size, but then some other limiting factor manifests itself. For many kinds of animals, the factor is the defense of territory, which protects the food supply for the territory owner. Lions roar, wolves howl, and birds sing in order to announce that they are in their territories and desire competing members of the same species to stay away.

Population can be controlled by predators, pathogens, or wars.

WARS PAST, PRESENT, FUTURE

Humans and chimpanzees are intensely territorial. That is the apparent population control hardwired into their social systems. What the events were that occurred in the origin of the chimpanzee and human lines—before the chimpanzee-human split of 6 million years ago—can only be speculated. I believe that the evidence best fits the following sequence. The original limiting factor, which intensified with the introduction of group hunting for animal protein, was food. Territorial behavior evolved as a device to sequester the food supply. Expansive wars and annexation resulted in enlarged territories and favored genes that prescribe group cohesion, networking, and the formation of alliances.

For hundreds of millennia, the territorial imperative gave stability to the small, scattered communities of *Homo sapiens*, just as they do today in the small, scattered populations of surviving hunter-gatherers. During this long period, randomly spaced extremes in the environment alternately increased and decreased the population size so that it could be contained within territories. These demographic shocks led to forced emigration or aggressive expansion of territory size by conquest, or both together. They also raised the value of forming alliances outside of kin-based networks in order to subdue other neighboring groups.

Ten thousand years ago, at the dawn of the Neolithic era, the agricultural revolution began to yield vastly larger amounts of food from cultivated crops and livestock, allowing rapid growth in human populations. But that advance did not change human nature. People simply increased their numbers as fast as the rich new resources allowed. As food again inevitably became the limiting factor, they obeyed the territorial imperative. Their descendants have never changed. At the present time, we are still fundamentally the same as our hunter-gatherer ancestors, but with more food and larger territories. Region by region, recent studies show, the populations have approached a limit set by the supply of food and water. And so it has always been for every tribe, except for the brief periods after new lands were discovered and their indigenous inhabitants displaced or killed.

The struggle to control vital resources continues globally, and it is growing worse. The problem arose because humanity failed to seize the great opportunity given it at the dawn of the Neolithic era. It might then have halted population growth below the constraining minimum limit. As a species we did the opposite, however. There was no way for us to foresee the consequences of our initial success. We simply took what was given us and continued to multiply and consume in blind obedience to instincts inherited from our humbler, more brutally constrained Paleolithic ancestors.

Excerpted from *The Social Conquest of Earth* by **Edward O. Wilson**, published in April by Liveright Publishing Corporation, a division of W. W. Norton & Company, Inc. Copyright © 2012.

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No, War Is Not Inevitable

E. O. Wilson is wrong: War is not our hereditary curse, and ending conflict could be much easier than he says.

by JOHN HORGAN

There is no scientist whom I admire more than Edward O. Wilson. He is an indefatigable investigator, explicator, and champion of all living things, from ants to humans, and he advances his views in prose more elegant and intricate than that of many accomplished novelists. His new book, *The Social Conquest of Earth*, eloquently elaborates upon his hope, first expressed in his monumental work *Sociobiology*, that science can help us achieve self-understanding and even, perhaps, salvation.

I have one serious complaint against Wilson, though. In his new book and elsewhere, he perpetuates the erroneous—and pernicious—idea that war is "humanity's hereditary curse." As Wilson himself points out, the claim that we are descended from a long line of natural-born warriors has deep roots—even the great psychologist William James was an advocate—but like many other old ideas about humans, it's wrong.

The modern version of the "killer ape" theory depends on two lines of evidence. One consists of observations of *Pan troglodytes*, or chimpanzees, one of our closest genetic relatives, banding together and attacking chimps from neighboring troops. The other derives from reports of intergroup fighting among hunter-gatherers; our ancestors lived as hunter-gatherers from the emergence of the *Homo* genus until the Neolithic era, when humans began settling down to cultivate crops and breed animals, and some scattered groups still live that way.

But consider these facts. Researchers did not observe the first deadly chimpanzee raid until 1974, more than a decade after Jane Goodall started watching chimps at the Gombe reserve. Between 1975 and 2004, researchers counted a total of 29 deaths from raids, which comes to one killing for every seven years of observation of a community. Even Richard Wrangham of Harvard University, a leading chimpanzee researcher and prominent advocate of the deep-roots theory of war, acknowledges that "coalitionary killing" is "certainly rare."

Some scholars suspect that coalitionary killing is a response to human encroachment on chimp habitat. At Gombe, where the chimps were well protected, Goodall spent 15 years without witnessing a single lethal attack. Many chimpanzee communities—and all known communities of bonobos, apes that are just as closely related to humans as chimps—have never been seen engaging in intertroop raids.

Even more important, the first solid evidence of lethal group violence among our ancestors dates back not millions, hundreds of thousands, or even tens of thousands of years, but only 13,000 years. The evidence consists of a mass grave found in the Nile Valley, at a location in modern-day Sudan. Even that site is an outlier. Virtually all other evidence for human warfare—skeletons with projectile points embedded in them, weapons designed for combat (rather than hunting), paintings and rock drawings of skirmishes, fortifications—is 10,000 years old or less. In short, war is not a primordial biological "curse." It is a cultural innovation, an especially vicious, persistent meme, which culture can help us transcend.

The debate over war's origins is vitally important. The deep-roots theory leads many people, including some in positions of power, to view war as a permanent manifestation of human nature. We have always fought, the reasoning goes, and we always will, so we have no choice but to maintain powerful militaries to protect ourselves from our enemies. In his new book, Wilson actually spells out his faith that we can overcome our self-destructive behavior and create a "permanent paradise," rejecting the fatalistic acceptance of war as inevitable. I wish he would also reject the deep-roots theory, which helps perpetuate war.

John Horgan directs the Center for Science Writings at Stevens Institute of Technology. His book *The End of War* was published in January.

BY CARL ZIMMER

The Hidden Epidemic: Tapeworms in the Brain

Parasitic worms leave millions of victims paralyzed, epileptic, or worse. So why isn't anyone mobilizing to eradicate them?

THEODORE NASH SEES ONLY a few dozen patients a year in his clinic at the National Institutes of Health in Bethesda, Maryland. That's pretty small as medical practices go, but what his patients lack in number they make up for in the intensity of their symptoms. Some fall into comas. Some are paralyzed down one side of their body. Others can't walk a straight line. Still others come to Nash partially blind, or with so much fluid in their brain that they need shunts implanted to relieve the pressure. Some lose the ability to speak; many fall into violent seizures.

Underneath this panoply of symptoms is the same cause, captured in the MRI scans that Nash takes of his patients' brains. Each brain contains one or more whitish blobs. You might guess that these are tumors. But Nash knows the blobs are not made of the patient's own cells. They are tapeworms. Aliens.

A blob in the brain is not the image most people have when someone mentions tapeworms. These parasitic worms are best known in their adult stage, when they live in people's intestines and their ribbon-shaped bodies can grow as long as 21 feet. But that's just one stage in the animal's life cycle. Before they become adults, tapeworms spend time as larvae in large cysts. And those cysts can end up in people's brains, causing a disease known as neurocysticercosis.

"Nobody knows exactly how many people there are with it in the United States," says Nash, who is the chief of the Gastrointestinal Parasites Section at NIH. His best estimate is 1,500 to 2,000. Worldwide, the numbers are vastly higher, though estimates on a global scale are even harder to make because neurocysticercosis is most common in poor places that lack good public-health systems. "Minimally there are 5 million cases of epilepsy from neurocysticercosis," Nash says.

He puts a heavy emphasis on *minimally*. Even in developed nations, figuring out just how many people have the illness is difficult because it is easy to mistake the effects of a tapeworm for a variety of brain disorders. The clearest proof is the ghostly image of a cyst in a brain scan, along with the presence of antibodies against tapeworms.

The closer scientists look at the epidemiology of the disease, the worse it becomes. Nash and other neurocysticercosis experts have been traveling through Latin America with CT scanners and blood tests to survey populations. In one study in Peru, researchers found 37 percent of people showed signs of having been infected at some point. Earlier this spring, Nash and colleagues published a review of the scientific literature and concluded that somewhere between 11 million and 29 million people have neurocysticercosis in Latin America alone. Tapeworms are also common in other regions of the world, such as Africa and Asia. "Neurocysticercosis is a very important disease worldwide," Nash says.

Cyst Attack

The alarming illness occurs when tapeworm larvae lose their way. Normally, *Taenia solium* has a life cycle that takes it from pigs to humans and back to pigs again. Adult tapeworms, living in the intestines of humans, produce up to 50,000 eggs apiece. The eggs are shed in the infected person's feces. Pigs swallow these eggs accidentally as they rummage for food on the ground. When the parasite eggs reach a pig's stomach, larvae hatch and burrow their way into the animal's bloodstream. Eventually they end up lodged in small blood vessels, typically in the animal's muscles. There they form cysts and wait until their host is eaten by a human. (Pork has to be undercooked for the tapeworms to complete their journey.)

But sometimes tapeworms take a wrong turn. Instead of going into a pig, the eggs end up in a human. This can occur if someone shedding tapeworm eggs contaminates food that other people then eat. When the egg hatches, the confused larva does not develop into an adult in the human's intestines. Instead, it acts as it would inside a pig. It burrows into the person's bloodstream and gets swept through the body. Often those parasites end up in the brain, where they form cysts.

The tapeworm larvae often get stuck in ventricles, or fluid-filled cavities, in the brain, sprouting

Carl Zimmer is an award-winning biology writer and author of *The Tangled Bank: An Introduction to Evolution*. His blog, The Loom, runs at blogs.discovermagazine.com/loom

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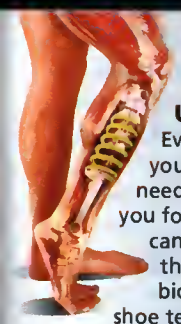

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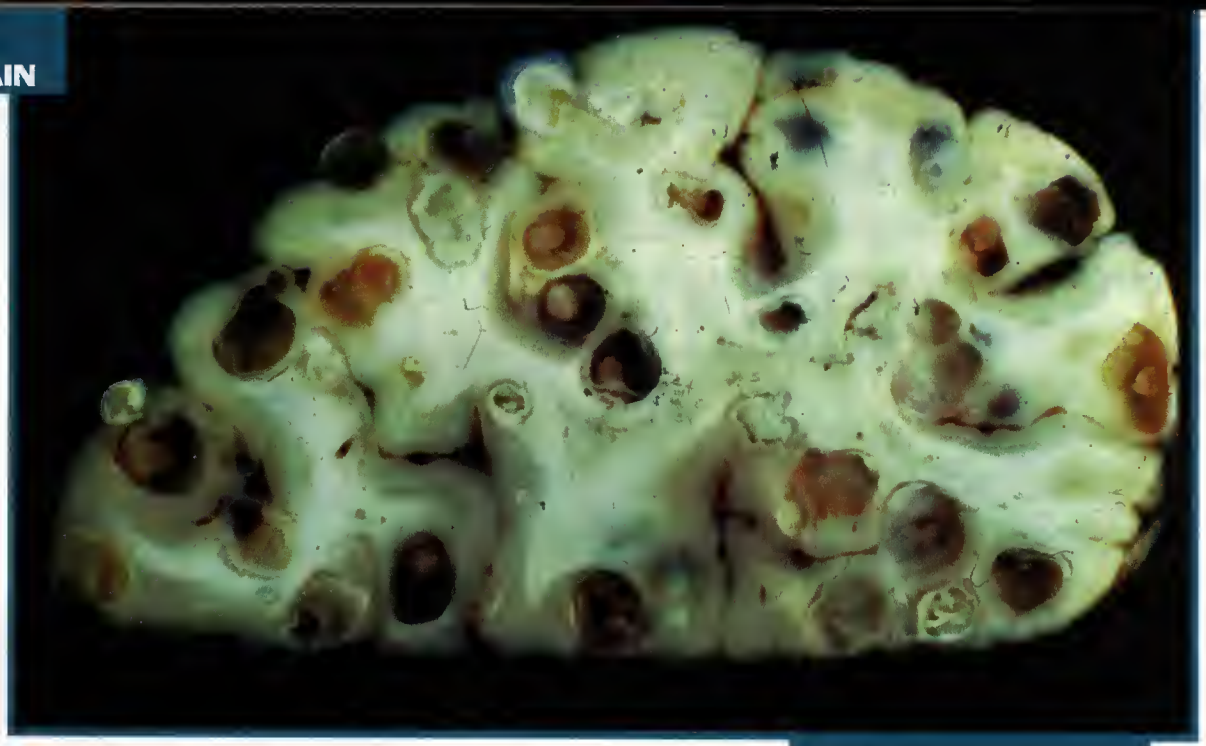

A human brain overrun with cysts from *Taenia solium*, a tapeworm that normally inhabits the muscles of pigs.

COURTESY THEODORE E. NASH, M.D.

grapelike extensions. In this way the worm actively cloaks itself from immune cells. Protected and well fed, its cysts can thrive there for years.

As a tapeworm cyst grows, it may push against a region of the brain and disrupt its function. It may get stuck in a passageway, damming the flow of cerebrospinal fluid. This impasse can cause hydrocephalus, or water on the brain, along with dangerously high pressure. A resulting brain hernia can result in stupor, coma, or death.

If a tapeworm doesn't cause these troubles, it may go unnoticed for its entire life. Eventually a tapeworm cyst that can't move on to its adult stage will die; this signals the host's immune system, eliciting a powerful attack and bringing its covert deception to an end. In many cases, the immune cells swiftly annihilate the revealed cyst, but often damage occurs. The immune system's attack on the cyst can cause the surrounding brain tissue to swell with inflammation. For reasons unknown, a calcified cyst can keep triggering these immune reactions for years after the parasite's death.

Although any cyst in a susceptible area of the brain can cause seizures, those lodged near regions that issue commands to muscles can trigger violent convulsions. One of Nash's patients suffered from tapeworm cysts that twisted around his brain stem. After the tapeworms died, the inflammation that followed was so severe it put the man in a coma.

"Thirty or 40 years ago, these patients just died. Surgeons would go in and see this mess and couldn't do much," Nash says. Fortunately, the situation is improving. Even his comatose patient woke up and, after a few years of off-and-on treatment, completely recovered. "Now the guy is doing quite well."

Breaking the Cycle

A great step forward came in the mid-1980s when praziquantel, the first drug able to kill tapeworm larvae in the brain, became widely available. But praziquantel proved too effective. It not only kills tapeworms but also triggers an immune reaction that causes brain swelling. "Paradoxically, we produce the disease we want to treat," Nash says.

Over the years Nash and others refined the treatment by combining praziquantel with other drugs that tamp down the immune system. It is far from a perfect solution, though. Sometimes the immune system still overreacts, requiring years of care for seizures and other symptoms. And immune-suppressant drugs like steroids have side effects of their own.

The hunt for better drugs to fight neurocysticercosis is not an easy process. The best way to test potential medicines on tapeworms is to get living cysts out of infected pigs. Nash and his colleagues recently set up a lab in Peru, where infected pigs are abundant, to do just that.

Although finding a better cure is important, Nash is more interested in preventing tapeworms from getting into human brains in the first place by breaking their life cycle. A favored strategy is identifying people who have adult tapeworms in their bodies and giving them drugs to kill the parasites. It is also possible to vaccinate pigs so that they destroy tapeworm eggs as soon as they ingest them.

None of this is rocket science—which makes Nash all the more frustrated that so little is being done. "I see this as a disease that can be treated and prevented," he says. But there are precious few resources available for treatment and little recognition of the problem. "All of this seems to be very feasible, but nobody wants to do anything about it."

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BY PAUL RAEBURN

The Wayward Planet Next Door

Venus could teach us a lot about our own world, yet we know shockingly little about it. It's time for NASA to explore Earth's evil twin.

ON THE AFTERNOON OF June 5 in the United States, a small black dot will crawl across the blazing face of the sun in one of the rarest celestial events: a transit of Venus, when our sister planet passes between us and our star. It won't happen again for 105 years.

That dot is our closest planetary neighbor and, in many ways, Earth's near-twin. Venus is 7,521 miles in diameter, just 5 percent smaller. It has an iron core and a thick, heat-trapping atmosphere. It orbits at about three-quarters the distance between Earth and the sun. If astronomers spotted such a planet orbiting another star, they would conclude it was an ideal place to search for life.

But in other ways, Venus is as enigmatic as that black dot against the sun. It is perpetually shrouded in dense clouds of sulfuric acid. The spacecraft that have explored it found no oceans, no protective magnetic field, and no active geology. The handful of old Soviet probes that descended to the planet's surface perished in an hour or two, destroyed by the 900-degree Fahrenheit temperature (hot enough to melt lead) and atmospheric pressure 90 times that on Earth.

Venus's contradictions lend it an unmistakable allure: How did a world so similar to our own turn out so different? The answers could tell a lot about the history of the solar system, about where to look for life in other planetary systems, and even about the future of Earth.

Astronomers believe that Earth and Venus were much more like twins when they formed 4.5 billion years ago. Back then the sun was dimmer, and Venus apparently was cooler. Studies of hydrogen molecules in the Venusian atmosphere by NASA's Pioneer-Venus probe indicate that the planet once had liquid water on its surface, perhaps even expansive oceans.

Life could have started and thrived under those conditions, says planetary scientist David Grinspoon of the Denver Museum of Nature & Science. But at some unknown point in its history, Venus reached a tipping point. The planet overheated and water on the surface rapidly evaporated, filling the atmosphere with water vapor; the vapor trapped more heat, which caused more evaporation, and so on. "It's a positive feedback loop," Grinspoon says. "The oceans basically boil."

From Identical to Evil

Planetary scientists still have to sort out exactly how Venus reached the point of no return. Grinspoon points to one important factor: its distance from the sun. Being 28 percent closer than Earth means that Venus receives about twice as much solar energy. Astronomers think that as the sun gradually grew hotter, it pushed Venus to a threshold temperature that set the runaway greenhouse effect in motion.

To confirm that hypothesis, scientists need to know how Earth-like Venus started out, and then how it transformed from temperate to unbearable. They want to understand how an atmosphere once rich in oxygen evolved into a layer of smothering gases, mostly carbon dioxide.

Determining exactly how Venus went over the edge would clarify whether Venus is the oddity—or Earth is. Last December scientists working with the Kepler space telescope discovered the mission's first planet in the "habitable zone" around another star, the location where temperatures could be mild enough to allow liquid water on a planet's surface. Kepler's goal is to determine the frequency of Earth-size planets in the habitable zones of stars; the news stirred hope that habitable planets are common throughout the galaxy.

But Venus too is an Earth-size planet tucked just within the habitable zone. If not for its thick atmosphere, Venus's surface would be cool enough to support liquid water. To seek out signs of life on other worlds, astronomers need to learn how to distinguish between planets with Earth-like climates and those that are more like Venus. "That's why we're interested in Venus," says Larry Esposito, a planetary scientist at the University of Colorado at Boulder. "We want to know: Throughout the universe, how many planets are good like us, or how many are evil like Venus?"

Understanding how good planets can go bad is also important for evaluating the future of our own world. Right now Earth is warming,

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Radar map of Venus (right) is colorized to simulate the true look of the hellish surface, where it is 900 degrees F everywhere, all the time.

and the chemistry of its atmosphere is changing. Scientists would love to take a detailed survey of Venus's atmosphere and use it to improve climate models of Earth. Venus may have many lessons to teach us about keeping Earth cool and habitable. In the very long term, Venus might be our destiny no matter what we do. In a billion years or two, the ever-brightening sun may send Earth past its tipping point too.

Roving Through Hell

With so much at stake, you might think that the nearest planet in the solar system would be a prime target for exploration. But it's quite the opposite. NASA has not sent a spacecraft to Venus since 1989, when the Magellan probe made detailed radar maps of the surface hidden under those sulfurous clouds. Researchers trying to make sense of Earth's sister world have to rely on those 20-year-old maps and on 30-year-old grainy photos from the Soviet landers. The European Venus Express satellite is currently in orbit around the planet, but it can take only indirect measurements of conditions beneath the clouds. If we really want to peel the layers off the mysterious planet, we need ambitious missions to explore the atmosphere and surface.

We have the technology to do that. Grinspoon envisions a balloon-borne craft that would drift through Venus's dense atmosphere, sniffing the gases throughout its journey to gather data about the planet's climatic history. The spacecraft could release smaller floating instruments that would search for microbes surviving in the clouds. Unlikely as it may seem, certain bacteria thrive under similar conditions on Earth. Perhaps some ancient Venusian inhabitants live on.

Developing a long-lived rover that could explore Venus's surface is a greater challenge—the circuitry in current interplanetary spacecraft would quickly fry there. Geoffrey Landis at NASA's Glenn Research Center in Cleveland thinks he can solve that problem with electronics made of silicon carbide (the material in sandpaper) that can operate for weeks in 900-degree temperatures. The technology, originally developed to function inside jet engines, could be available for an interplanetary mission within a few years.

Like Spirit and Opportunity, the robots that have successfully roamed on Mars, Landis's long-range rover would have a mechanical arm to study rocks and a high-resolution camera. Landis has even picked a potential landing site for his heat-proof creation: Maxwell Montes, a strangely radar-reflective mountain range, where the iron-rich surface may have interacted with sulfuric acid to form a coating of fool's gold.

Right now NASA is moving the other way, pulling funds away from planetary exploration as its budget dwindles. But a Venus mission is exactly the type of high-frontier undertaking that could reignite the passion the agency once inspired.

"This is what NASA should be doing: pushing the edge and doing things nobody else can do," Landis says. Venus is the perfect place to do that, especially with so much at stake and so much left to learn. Venus, Landis says, "is so unexplored that we don't even know what we need to know."

Paul Raeburn writes about science, culture, and policy, and he blogs for the Knight Science Journalism Tracker. He is a frequent contributor to DISCOVER.

FROM LEFT NASA; STOCKTREK IMAGES/GETTY IMAGES

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CONTINUED FROM PAGE 39

Richard Cooper, a former Sealab and Tektite aquanaut and a longtime University of Connecticut professor of marine sciences who died last year. The group hopes to raise the $35 million it will need to create the habitat, a boxy structure that would accommodate 25 aquanauts at depths up to 60 feet.

THE MOST FORWARD-THINKING of the new undersea habitats may be a vessel called SeaOrbiter, currently funded by an international consortium. The vertically oriented structure, which stands 170 feet tall, is a massive buoy that looks like the fusion of a spinnaker sail and the Starship *Enterprise*. Designed by the renowned French architect Jacques Rougerie, SeaOrbiter would float and drift with currents, with more than half of the towering craft below the waterline at any given time. A one-fifteenth scale model has passed muster in a Norwegian wave tank. The submerged part of SeaOrbiter is designed to house a team of a half-dozen saturation divers, about a third of the planned crew, at a storage depth of about 40 feet. From one of the vessel's lower modules, they would be able to swim directly into the sea or ride an elevator down to 150 feet. A two-person submersible could dive from the mother ship to 2,000 feet.

SeaOrbiter: The planned mobile vessel also qualifies as a habitat because its scientists will be able to live underwater for weeks or months at a time.

"We just received funding to go forward with this project, and we're going to realize it, and it's quite incredible," says Bill Todd, a project manager of NASA's Neemo group, which is tasked with running experiments and training sessions at Aquarius. Todd has worked with the SeaOrbiter group for a decade. Years of engineering evaluations have been done, as have final drawings and technical schematics, and a contract has been hammered out with a shipyard in France to build SeaOrbiter. They could be cutting metal on the project in time to deploy the craft on its first mission by next year. "It's going to revolutionize 'inner space' exploration," Todd promises.

Finally there is Dennis Chamberland, a NASA engineer who has been trumpeting the cause of aquatic habitats for years. Chamberland leads a private effort to build a prototype underwater community. Though he prefers not to discuss the details with members of the press, his sci-fi-sounding effort, Atlantica Expeditions, calls for a true undersea colony, where "families live and work" and "children go to school." He says his vision of a high-tech cluster of habitats would deliver "a new ocean civilization whose most important purpose will be to continuously monitor and protect the global ocean environment."

Chamberland's first expedition, Atlantica 1, planned for the summer of 2014, aims to send three aquanauts on a 100-day underwater mission, longer than any yet recorded, to test "systems intended for permanent human residence of the undersea world." But most important, he is designing his habitats so they will not require compression diving. "Just like a moon base, the permanent facilities of the new world of Aquatica will have a constant, safe, close to Earth-normal living environment with lockout access to the remote and extreme external environment," he says. "It is a preeminent paradigm shift that allows the frontier to be opened where it was not practical before."

If that sounds like a habitat too far, more pragmatic plans are brewing all the time back in Koblick's office. The topic of the day is marine archaeology, a job for which a habitat could be the perfect tool (see the interview with George Bass, page 40). The marine archaeologist's work can be as detailed, painstaking, and slow-paced as that of terrestrial counterparts, so having a base near the site of a shipwreck would offer enormous advantages over repeated short-duration dives.

The key for Koblick is that archaeology could underwrite new habitats, providing a money model for bases on the seafloor. Toward that end, he recently asked the European Union to fund excavation of a 500-year-old wreck off the coast of Croatia. The request was denied, but it will not be his last. What remains as clear as the view out the window of La Chalupa is that the dream lives on.

Ben Hellwarth is the author of ***Sealab: America's Forgotten Quest to Live and Work on the Ocean Floor.***

Did you ever consider that when people keep their balance, it is not by their intent? Instead, they are acting on the intent of a natural law we call gravity.

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20 THINGS YOU DIDN'T KNOW ABOUT SEX

By Gregory Mone

1. Marvin Gaye breaks it down in "Let's Get It On"—what could be simpler? Psychologists at the University of Texas at Austin take a different view. They surveyed 444 people and found 237 reasons why people have sex. **2.** "I was drunk" made the top 50 for women; "to get a favor" made the top 50 for men. **3.** Believe it or not, biologists cannot agree on the reason for sex either. **4.** The standard evolutionary argument is that the mixing of DNA between two members of a species introduces more variation into the gene pool. But asexual reproduction is far more efficient. **5.** One leading hypothesis suggests that sex won out over DIY as a defense against parasites, which would be less harmful in a varied gene pool. **6.** In 2009 a team of scientists bolstered this idea by monitoring two groups of snails—one that reproduced sexually, the other asexually. Over time, the self-starters became more susceptible to parasites, dying off at a faster rate. **7.** Not that sexual reproduction is exactly disease free. About 3.7 million Americans carry the most common sexually transmitted parasite, *Trichomonas vaginalis*. **8.** You think we've got troubles? The mating call of certain Hawaiian male crickets attracts a fly that deposits parasitic larvae. When the larvae mature, they burst out of the cricket, killing it instantly. **9.** Some male crickets have a mutation that prevents them from making the call, helping them elude the deadly flies. The sneaky-quiet ones hang out around the vulnerable singing crickets so they can still meet girls. **10.** One of nature's most elaborate mating rituals belongs to the nursery web spider. Males wrap a collection of gifts—typically edible insects—in silk bundles and present them to potential mates. **11.** In some cases, male spiders try to sneak in worthless items like the leftovers of already-eaten bugs, so females have learned to examine the gift. Danish researchers found that far greater success was awarded to males who had a nicely wrapped package. **12.** When the mood strikes a male Muscovy duck, the corkscrew-shaped embodiment of its excitement shoots to a fully extended 8-plus inches in just 0.36 second. **13.** Battle of the sexes: The corresponding female organ is also corkscrewed—but in the opposite direction. **14.** Studies of human male inflation, a.k.a. "phallometry," often use a sealed, gas-filled cylindrical chamber that fits snugly around the object of interest and registers the amount of gas displaced. **15.** Equivalent studies in women use a photoplethysmograph, a probe that measures pulse and changes in blood volume in the vagina. **16.** Psychologist Meredith Chivers of Queens University in Ontario, Canada, used similar devices to study objectively how men and women responded to erotic films. Heterosexual men, as well as homosexual men and women, became aroused while viewing attractive members of their preferred sex engaged in nonsexual activities, such as walking on a beach. For heterosexual women, a naked strolling guy didn't do much. **17.** Yet Chivers found that women exhibited increased blood flow when watching bonobos mate, even though they did not report feeling aroused. **18.** Chivers speculates that increased blood flow (and associated lubrication) in response to witnessed sexual behavior could be a biological response that prepares females for sudden, unsolicited penetration. **19.** Ohio State University psychologist Terri Fisher tested the oft-repeated claim that men think about sex every seven seconds (which translates to 8,000 instances daily) by having 283 students carry around a golf-score counter and click each time they thought about sex, food, or sleep. In reality, the young men's fancy turned to sex merely 19 times per day. **20.** The young women in the study had 10 such daily thoughts, on average, and both genders thought about food and sleep just as often as sex.

The Kiss **by Pablo Picasso (1969).**

Gregory Mone is the author of the new novel *Dangerous Waters: An Adventure on Titanic*. There is no sex in the story.

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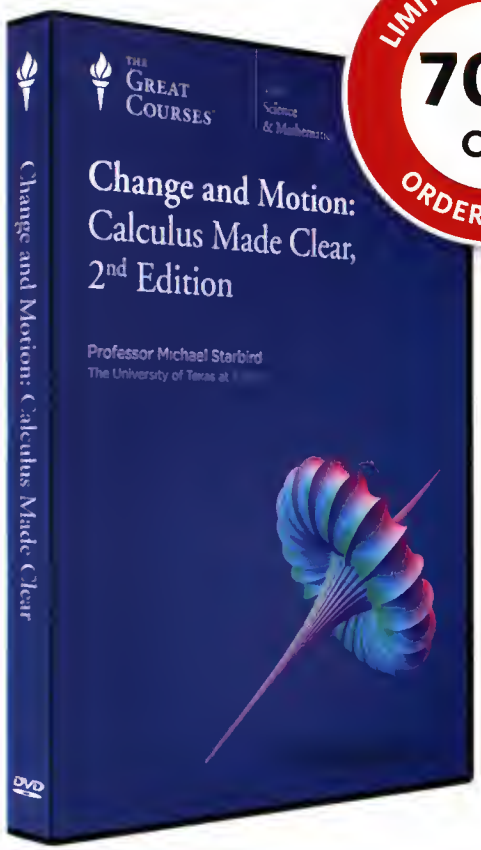

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PROGRESSIVE

George Bass

The pioneering underwater archaeologist ignored academics

off the coast of Turkey, along with sites from many other periods. Along the way, he transformed underwater archaeology from an amateur's pastime to a modern scientific discipline. Those achievements earned him a National Medal of Science in 2002. Now a professor emeritus at Texas A&M University, where he founded the Institute of Nautical Archaeology, Bass reflected on his storied career with DISCOVER senior editor (and passionate lover of archaeology) Eric A. Powell.

PHOTOGRAPHY BY RANDAL FORD

Why go underwater to study the ancient past, when research is so much easier on land?

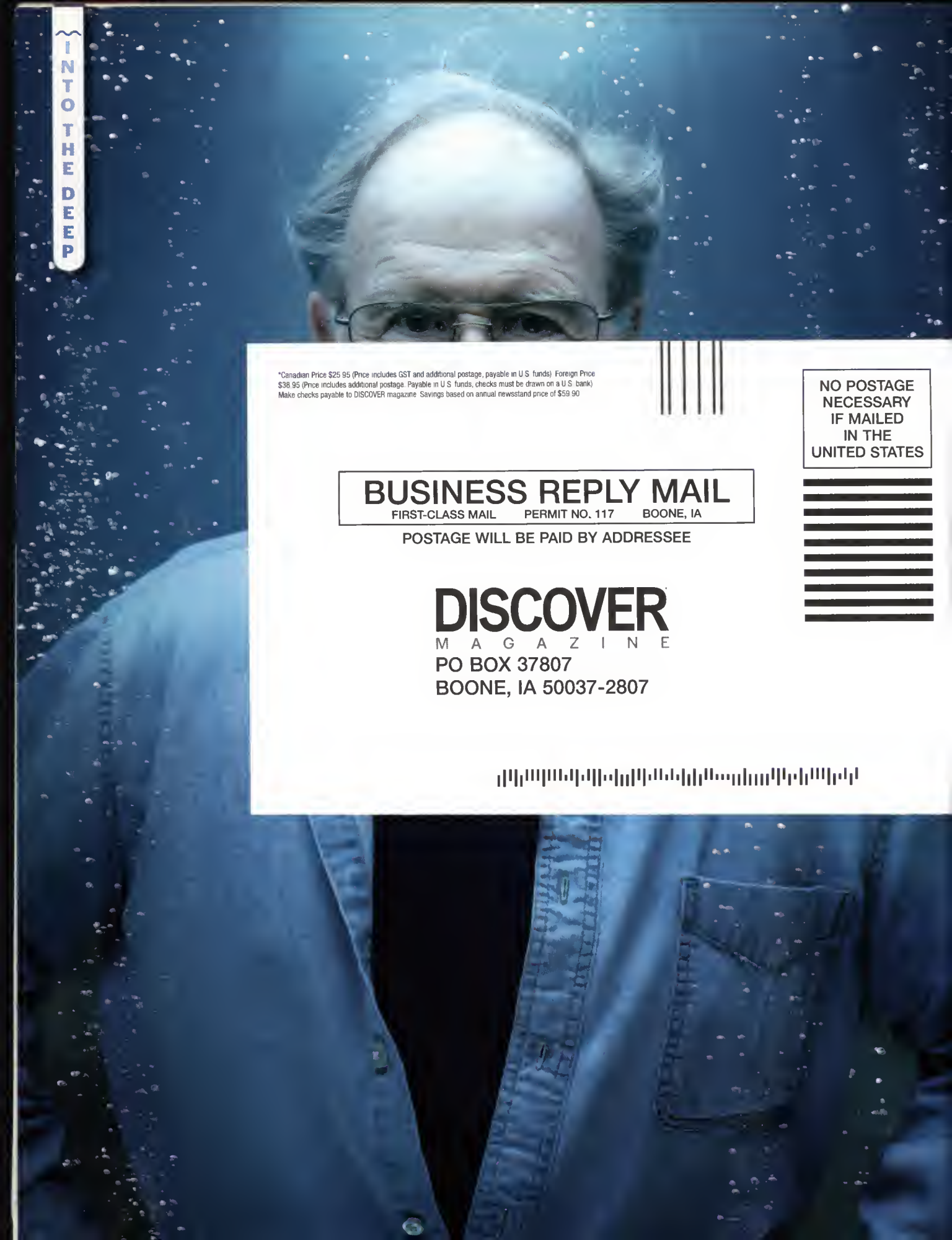
Underwater artifacts are protected against ...tive agent of all, which is us. ...s and break them. They drop ...break them. They burn mar... ...me. They melt down bronze ... roofs. Also, there are certain ...mply not going to be found ...naterials, because they don't ...ry long out of the water. The ...o underwater is that it's the ...dence of ship hulls, which ...t to ancient cultures as archi... ...nything. There's always been ...ort goods or ideas as cheaply ...a quantity as possible. For ...history, that meant building ...could.

What can you learn from a ship hull?

Since at least the Bronze Age, seafaring has been key to cultural progress. Ships are in some cases the most technologically advanced equipment a culture would develop—their space shuttles. So to really understand the ancients, you have to be able to understand how they approached the sea, and the only way to do that is to excavate shipwrecks. And those ships only sank once, so they can give you incredibly precise dates.

Have you always been drawn to ships and the sea?

I grew up in Annapolis, Maryland, where my father taught English at the Naval Academy. My brother and I made a diving helmet out of a tin square that we cut out and put glass in



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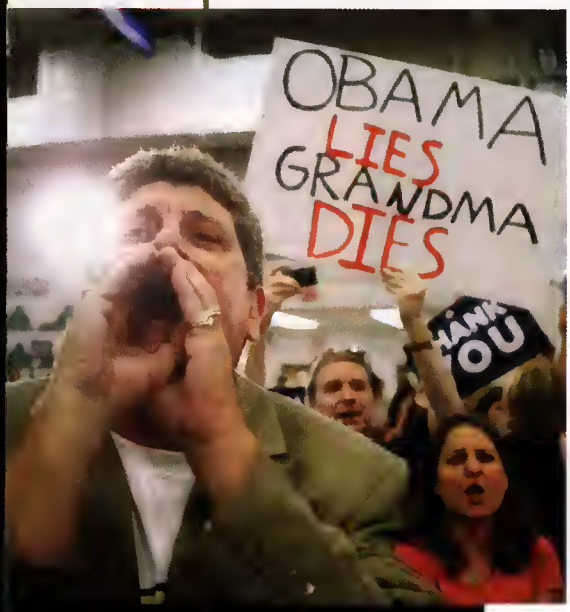
THE CONTRARIAN: Elizabeth DeVita-Raeburn

The Case Against Patient Choice



Limiting options could be good news for grandr

CONVENTIONAL WISDOM notch health care depend preserving a diversity of o and patient choice.

THE CONTRARIAN: Elizab DeVita-Raeburn says we n fewer choices and more e

AMERICANS HAVE ALWAYS the right to make their ow choices, especially about h care. So it is not surprising federal health-care reform larly known as Obamacare sparked fears that the wis counsel of doctors could be replaced by the rubber stamps of government bureaucrats. The common belief is that only doctors truly k what works and what doe

But the argument falls apart because most doctors lack the evidence to compare various treatments in any absolute way. In 2009 the nongovernmental Institute of Medicine (IOM) released a list of 100 disorders, including lower back pain, atrial fibrillation, and early prostate cancer, that it says require research analyzing which treatments work best for different groups of patients.

Having lots of treatment options is useless if we have no way to intelligently choose between them. That is exactly what we need to remedy in our health-care system: Instead of offering a vast array of choices, we must eliminate options that are needlessly risky and expensive by providing more proof of what works best. The government has pledged $500 million annually, beginning in 2014, to do exactly that. Comparing

Funding more of these studies, guided by the IOM recommendations, is critical for strengthening American health care. Patients may like having many choices, but they will love knowing the right one.

OFF THE CHARTS

Largest Map of Dark Matter Across the Cosmos

It isn't easy creating a map of something invisible, but that's what astronomers did earlier this year when they unveiled the largest-ever survey of dark matter.

Astronomers believe dark matter makes up a quarter of the universe, yet it does not absorb or emit light, and nobody has detected a particle of it. Fortunately, dark matter does reveal itself in a subtle way: As light approaches a clump of the mysterious stuff, it bends around it in a phenomenon known as gravitational lensing. The more massive the clump, the more the light bends. Astrophysicists Catherine Heymans of the University of Edinburgh and Ludovic Van Waerbeke of the University of British Columbia spent five years painstakingly cataloging this lensing in 10 million galaxies with the Canada-France-

Blue denotes dark matter in cluster Abell 520.

JEE, ITY; ISTOCK

SEA BASE ALPHA

Key Largo, where
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IF THERE IS ANY PLACE ON EARTH YOU MIGHT EXPECT TO FIND them—the true believers in the imminent coming of manned undersea outposts or spectacular domed colonies on the ocean floor—it would be here, in Key Largo. This first major stop along the 100-mile Overseas Highway to Key West is home to the world's only underwater hotel, the only continuously operating underwater lab and classroom, and the only undersea research base. And it is in Key Largo that you find divers like Ian Koblick, whose even tan hints at his lifetime of outdoor ventures. His hair and trademark goatee are graying, although for a septuagenarian he looks as if he takes regular dips in the Fountain of Youth. Like so many others along this steamy island chain, he's wearing shorts and a billowing Hawaiian shirt. No matter that he is seated behind a large desk in the kind of high-backed executive chair more often associated with Brooks Brothers.

The wood-paneled walls around Koblick's office are filled with memorabilia that attest to his years as an undersea pioneer and a genuine player in a decades-long quest to turn ordinary divers into "aquanauts," the name applied to those equipped to live on the seabed, much as crews launched into space get to be called astronauts.

D.J. ROLLER/LIQUID PICTURES 3D

vents host evolutionarily ancient lineages of microorganisms and may have been a cradle supporting early life on the planet.

As a home for sensitive scientific equipment, though, Axial Seamount carries big risks. "It's pretty mind-boggling," says chief systems engineer Chuck McGuire. "We're building this thing worth hundreds of millions to d purp harsl plan

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the sensing instruments so that no single eruption can take out everything. Sensors at the volcano and back at Hydrate Ridge will include seismometers, high-def video cameras, temperature and pH sensors, and current meters. The network will also test cutting-edge tools like an underwater mass spectrometer—which can determine the composition of a substance on the spot—and a microbial sampler to sequence DNA on site.

At Axial, the team on the *Thompson* sends Ropos to locate the fiber-optic cable, laid down just a few weeks earlier. Ropos traces the cable's route on the seafloor as Delaney and the others watch the video feed, rotating in shifts, to make sure the cable looks safe, with no sections dangling from rocks or rubbing against rough surfaces. Everything looks fine—except for one segment, which is draped over a previously unknown hydrothermal system. The site is like a hidden city on the seafloor, with sulfide vents towering 120 feet tall, some emitting hot black fluids.

them up to the master cable. Then in 2013 they will plug in their instruments using more than 40 miles of extension cords. By 2014, sensor-carrying robots that climb up and down wires—still under construction—will arrive, completing the initial installation. The other five OOI sites should be up and running by then as well.

To Delaney, that is not an end point; it is just the beginning. "We're pushing the envelope with this project," he says, "but we'll be a test bed for future observatories around the world." More than 95 percent of the ocean remains unexplored, and several other countries are already working on parallel programs. Last summer Japan completed a cabled seafloor network called Donet, focused on offshore earthquakes and tsunamis. A cable links 20 sites, each of which hosts seismometers along with pressure sensors that can pick up changes in the shape of the seafloor. Project leader Yoshiyuki Kaneda hopes that such data will provide clues about the build-up of pressure in the crust that leads to large earthquakes.

entists have barely begun to study.

"No one would ever allow a spacecraft to take off if its engineers didn't have a thorough understanding of its life-support system," he says. "We know so little about that system here on Earth, and the ocean is a huge part of it. We have to learn to identify when it might be approaching tipping points, so that we can respond and manage them. We can't do that yet. We're not wise enough. But this is a step in the right direction."

Jennifer Barone is senior associate editor at DISCOVER.

No, War Is Not Inevitable

E. O. Wilson is wrong: War is not our hereditary curse, and ending conflict could be much easier than he says.

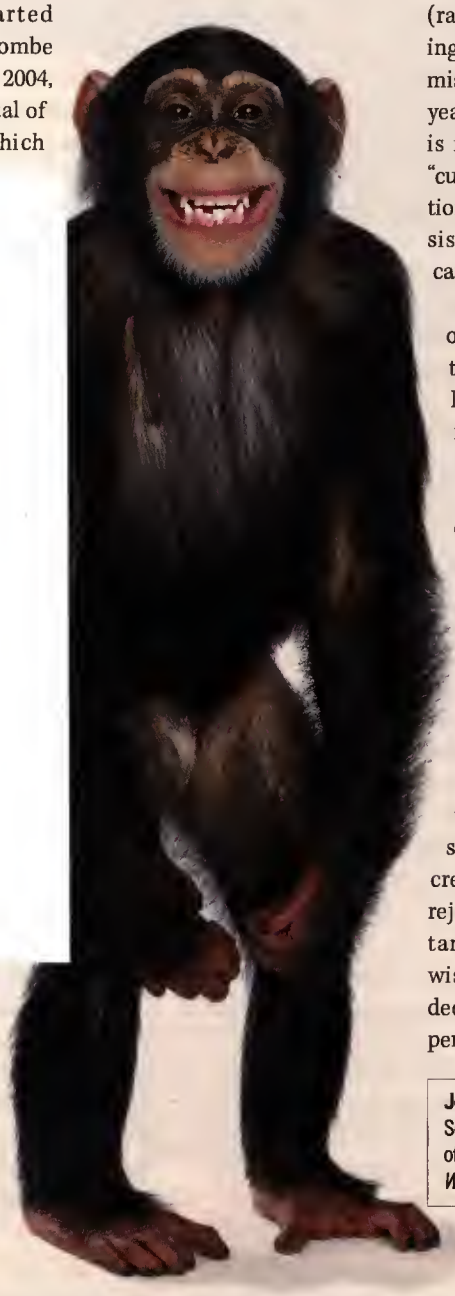
by JOHN HORGAN

There is no scientist whom I admire more than Edward O. Wilson. He is an indefatigable investigator, explicator, and champion of all living things, from ants to humans, and he advances his views in prose more elegant and intricate than that of many accomplished novelists. His new book, *The Social Conquest of Earth*, eloquently elaborates upon his hope, first expressed in his

and attacking chimps from neighboring troops. The other derives from reports of intergroup fighting among hunter-gatherers; our ancestors lived as hunter-gatherers from the emergence of the *Homo* genus until the Neolithic era, when humans began settling down to cultivate crops and breed animals, and some scattered groups still live that way.

But consider these facts. Researchers did not observe the first deadly chimpanzee raid until 1974, more than a decade after Jane Goodall started watching chimps at the Gombe reserve. Between 1975 and 2004, researchers counted a total of 29 deaths from raids, which zee communities—and all known communities of bonobos, apes that are just as closely related to humans as chimps—have never been seen engaging in intertroop raids.

Even more important, the first solid evidence of lethal group violence among our ancestors dates back not millions, hundreds of thousands, or even tens of thousands of years, but only 13,000 years. The evidence consists of a mass grave found in the Nile Valley, at a location in modern-day Sudan. Even that site is an outlier. Virtually all other evidence for human warfare—skeletons with projectile points embedded in them, weapons designed for combat (rather than hunting), paintings and rock drawings of skirmishes, fortifications—is 10,000 years old or less. In short, war is not a primordial biological "curse." It is a cultural innovation, an especially vicious, persistent meme, which culture can help us transcend.



The debate over war's origins is vitally important. The deep-roots theory leads many people, including some in positions of power, to view war as a permanent manifestation of human nature. We have always fought, the reasoning goes, and we always will, so we have no choice but to maintain powerful militaries to protect ourselves from our enemies. In his new book, Wilson actually spells out his faith that we can overcome our self-destructive behavior and create a "permanent paradise," rejecting the fatalistic acceptance of war as inevitable. I wish he would also reject the deep-roots theory, which helps perpetuate war.

John Horgan directs the Center for Science Writings at Stevens Institute of Technology. His book *The End of War* was published in January.

evolved it independently in response to parallel pressures of natural selection and opportunities encountered in the African homeland. From the remarkable similarity in behavioral detail between the two species, however, and if we use the fewest assumptions required to explain it, a common ancestry seems the more likely choice.

The principles of population ecology allow us to explore more deeply the roots of mankind's tribal instinct. Population growth is exponential. When each individual in a population is replaced in every succeeding generation by more than one—even by a very slight fraction more, say 1.01—the population grows faster and faster, in the manner of a savings account or debt. A population of chimpanzees or humans is always prone to grow exponentially when resources are abundant, but after a few generations even in the best of times it is forced to slow down. Something begins to intervene, and in time the population reaches its peak, then remains steady, or else oscillates up and down. Occasionally it crashes, and the species becomes locally extinct.

Population can be controlled by predators, pathogens, or wars.

What is the "something"? It can be anything in nature that moves up or down in effectiveness with the size of the population. Wolves, for example, are the limiting factor for the population of elk and moose they kill and eat. As the wolves multiply, the populations of elk and moose stop growing or decline. In parallel manner, the quantity of elk and moose are the limiting factor for the wolves: When the predator population runs low on food, in this case elk and moose, its population falls. In other instances, the same relation holds for disease organisms and the hosts they infect. As the host population increases, and the populations grow larger and denser, the parasite population increases with it. In history diseases have often swept through the land until the host populations decline enough or a sufficient percentage of its members acquire immunity.

There is another principle at work: Limiting factors work in hierarchies. Suppose that the primary limiting factor is removed for elk by humans' killing the wolves. As a result the elk and moose grow more numerous, until the next factor kicks in. The factor may be that herbivores overgraze their range and run short of food. Another limiting factor is emigration, where individuals have a better chance to survive if they leave and go someplace else. Emigration due to population pressure is a highly developed instinct in lemmings, plague locusts, monarch butterflies, and wolves. If such populations are prevented from emigrating, the populations might again increase in size, but then some other limiting factor mani-

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the following seque
iting factor, which intensified with the introduction of group hunting for animal protein, was food. Territorial behavior evolved as a device to sequester the food supply. Expansive wars and annexation resulted in enlarged territories and favored genes that prescribe group cohesion, networking, and the formation of alliances.

For hundreds of millennia, the territorial imperative gave stability to the small, scattered communities of *Homo sapiens*, just as they do today in the small, scattered populations of surviving hunter-gatherers. During this long period, randomly spaced extremes in the environment alternately increased and decreased the population size so that it could be contained within territories. These demographic shocks led to forced emigration or aggressive expansion of territory size by conquest, or both together. They also raised the value of forming alliances outside of kin-based networks in order to subdue other neighboring groups.

Ten thousand years ago, at the dawn of the Neolithic era, the agricultural revolution began to yield vastly larger amounts of food from cultivated crops and livestock, allowing rapid growth in human populations. But that advance did not change human nature. People simply increased their numbers as fast as the rich new resources allowed. As food again

consume in blind obedience to instincts inherited from our humbler, more brutally constrained Paleolithic ancestors.

Excerpted from *The Social Conquest of Earth* by **Edward O. Wilson**, published in April by Liveright Publishing Corporation, a division of W. W. Norton & Company, Inc. Copyright © 2012.

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